Version 0.26

**NASA High Performance Computing and
Communications (HPCC) Program**

Earth and Space Sciences (ESS) Project

Increasing Interoperability and Performance of Grand Challenge Applications in the Earth and Space Sciences

NASA Cooperative Agreement Notice (CAN)
Soliciting Proposals for
Research in High Performance Computing

CAN–<__insert CAN number__>
Issued <__insert date__>, 1999

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

NASA HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance of Grand Challenge Applications in the Earth and Space Sciences

TABLE OF CONTENTS

CAN Overview

This NASA Cooperative Agreement Notice (CAN) is a solicitation by the Earth and Space Science Enterprises requesting proposals for Earth and Space Sciences (ESS) Project Grand Challenge Investigations. The ESS Project is a cross-cutting information technology activity striving to enable the NASA science Enterprises and their field centers to meet increasing mission requirements more effectively and efficiently. Guided by the strategic plans of the Enterprises, ESS research increases NASA's capability to produce, analyze, and understand its science and mission data while reducing the investment in money and time required to do so.

The goal for selecting Investigations is to enable production ready high performance Earth and space science computational applications which analyze or interpret NASA Enterprise observational mission data. Successful proposed Investigations are expected to develop a significant high end computing application using accepted software engineering practices which:

- Addresses a significant element of one of NASA's Enterprises' Strategic Plans
- Incorporates the use of NASA data to understand Earth or space science phenomena

Proposed applications should be incorporated within a software framework which:

- Fosters reusability among software components and portability among high end computing architectures
- Reduces the time required to modify research application codes
- Structures systems for better management of evolving codes
- Enables software exchange between major centers of research

As a focused subset of this solicitation, the ESS Project is inviting teams to propose applications and frameworks that contribute to the development of an integrated Earth System Modeling Framework for the Earth Science Enterprise. Significant ESS support will be made available to teams selected to participate in this framework activity.

Payments to all selected Investigator Teams will be based on meeting milestones that are finalized during the negotiation phase of successful proposals. Team milestones will include attaining application code interoperation and performance goals required by ESS Project Milestones described in Section 2. The ESS Project will provide winning Investigations with services focused on high end computing, including access to large teraflop/s scale testbeds, code performance evaluation and optimization, visualization support, applications middleware development, and wide area network (WAN) research support.

This is the third round of ESS Grand Challenge Investigations. Teams are competed periodically to adjust the work of the project and assure that it continues to be responsive to the needs of key NASA scientific research areas and flight missions. New rounds of Team selection are carried out through issuance of a NASA CAN, followed by a full peer review, with final selection made by Enterprise science program management at NASA Headquarters. The objectives of this Round-3 CAN are significantly different from the Round-2 CAN [see Section 5 in Appendix E] due to strong alignment with the new Earth and Space Science Enterprise Strategic Plans and the recommendations made recently by the President's Information Technology Advisory Committee (PITAC).

Participation in this program is open to all categories of organizations: educational institutions, industry, nonprofit institutions, NASA centers, and other Government Agencies.

This CAN is being funded through the ESS Project. Approximately $18 million spread evenly over three years is currently in the President's budget request for NASA to fund the Grand Challenge Investigator proposals. However, funding for FY 2000 and subsequent years is dependent on the availability of funds appropriated by the U.S. Congress. The decision as to which Grand Challenges to support will be based on the Evaluation Criteria found in Section 11 of Appendix G, and available

funding. Depending upon the responses to this CAN and available resources, the Government contemplates selecting between eight and ten Grand Challenge Investigator proposals to fund, but it reserves the right to enter into cooperative agreements with fewer than eight or more than ten proposers and for amounts totaling less than the entire funding level, or decide not to select any proposal to fund. Annual funding levels are anticipated at between $300K and $1M per award.

The Cooperative Agreements resulting from this announcement are intended to continue for three years beginning in late FY 2000, pending continued program funding availability. The provisions of the cooperative agreements will be negotiated with selected Proposers prior to award.

Proposals are due on January 2, 2000. Proposers selected to begin negotiations are expected to be notified by April 1, 2000. A proposal that is scientifically and programmatically meritorious under this CAN, but that cannot be accepted during its initial review, may be included in subsequent reviews unless the offerer requests otherwise. Appendix A describes the required and optional milestones for Investigator proposals. Appendix B discusses use of software frameworks for Earth and space sciences applications. Appendix C presents the concept of the Earth System Modeling Framework. Appendix D describes the computing testbeds for the use of Investigators selected by this CAN. Appendix E contains an overview of the ESS Round-3 activities of which this CAN is a major component. Appendix F contains World Wide Web References to additional project and program information which may be helpful in responding to this solicitation. Appendix G gives guidance for preparation of Investigator proposals and states the evaluation criteria. Appendix H contains information about the preproposal conference. Appendix I provides definitions of terms. Appendix J defines acronyms.

Identifier:	CAN-<__insert CAN number__>
Selecting Official:	Dr. Ghassem Asrar Associate Administrator, Earth Science Enterprise NASA Headquarters Washington, DC 20546-0001
Point of contact for questions regarding the solicitation:	Mr. Omar Spaulding NASA Headquarters, Code YF Washington, DC 20546-0001 Telephone: 202-358-0777 FAX: 202-358-____ E-mail: ospauldi@hq.nasa.gov
Point of contact for implementation:	Ms. Ann Kearney NASA/Goddard Space Flight Center Code 219 Greenbelt, MD 20771 Telephone: 301-614-5610 FAX: 301-614-5619 E-mail: akearney@pop200.gsfc.nasa.gov

This solicitation is available electronically via the World Wide Web at: <__ URL__>

Your interest in participating in this cooperative agreement notice is appreciated.

Original signed by:

Dr. Ghassem Asrar   Dr. Ed Weiler
Associate Administrator   Associate Administrator

Earth Science Enterprise   Space Science Enterprise

1. Introduction

This NASA Cooperative Agreement Notice (CAN) is a solicitation by the Earth and Space Science Enterprises for scientific proposals that will enable NASA's continued progress toward solving Grand Challenge problems in the Earth and space sciences using scalable parallel computer systems. A *Grand Challenge* is a fundamental problem in science or engineering with potentially broad economic, political, and/or scientific impact, that may be advanced through the application of high performance computing (HPC) resources.

Grand Challenge Investigator proposals, described in Appendix G, are requested for cooperative research directed at the development, testing, and use of advanced high performance applications codes employing frameworks for interoperation. The term *framework* describes a software architecture that consists of several large components and the bonds between them. Frameworks are employed to:

- Foster reusability among software components and portability among high end computing architectures
- Reduce the time required to modify research application codes
- Structure systems for better management of evolving codes
- Enable software exchange between major centers of research

The Grand Challenge Investigator Teams selected through this CAN will be seeking to advance the performance of proposed specific application codes and expand their interoperability with other related codes within self defined multidisciplinary scientific communities through the use of software frameworks. In particular, development of an Earth System Modeling Framework (ESMF) will be a high priority of ESS, though investigations in other areas of the Earth and space sciences are also encouraged. Customers of the technology to be developed by Round-3 Investigators include NASA scientific research programs and flight missions that require mature Grand Challenge codes for use in production and operational computing environments. Investigator Teams selected by this CAN will be required to make their improved application codes and associated framework freely available on the web in source form. A separate related solicitation for 'plug-in' software applications codes to enrich the environment of the frameworks developed by the selected Teams will be run by ESS following the start of work by the Round-3 Grand Challenge Investigators. Investigators will be expected to assist the project in selecting plug-in solicitation awardees and provide their frameworks to awardees.

Selected Investigator Teams will be provided access to significant computing resources and applications support, including a Teraflop/s Scalable Testbed and a Commodity Based Testbed, described in Appendix D. Teams selected will also be eligible to receive a range of related support in areas described in the next section.

2. Background

The ESS Project is part of the NASA HPCC Program, a critical element of the Federal program in Computing, Information and Communications (CIC).

The overall goal of the ESS Project is to demonstrate the potential afforded by balanced teraflop/s systems' performance to further our understanding of and ability to predict the dynamic interaction of physical, chemical and biological processes affecting the Earth, the solar-terrestrial environment, and the universe. Since its inception in 1992, ESS has pursued

this goal through selection and support of two rounds of Grand Challenge Investigations. It is intended that this CAN result in the selection of the third round.

Most ESS Round-2 Investigations achieved the performance targets set out in the 1995 ESS Round-2 CAN, resulting in one to two orders of magnitude increase in performance of their codes. These Investigator codes have emerged as powerful tools for performing important work for the Agency. These highly capable scalable codes have exposed new issues that are as important as performance: interoperability of high performance codes, portability of applications among the variety of high performance architectures, and management of the complexity of resulting coupled models.   It has become evident that additional performance, though necessary, is not sufficient to make a code useful for support of NASA research and missions. The cost to adapt existing high performance research codes to function with suites of NASA research or production codes for evaluation and eventual adoption and use may be prohibitively high. This is because code interoperability, which often exists among code components within specific research groups, rarely exists between these groups and there are many such groups. In some cases, several Agencies such as NASA, NSF, DOE, and DOD fund multiple research groups within a modeling community, all researching advanced models, but these models lack the ability to interoperate. This situation is not a significant issue when the primary products of the research groups are research findings shared through scientific papers, but with the emergence of powerful modeling codes as key tools of NASA science and mission support, preparation of these codes for ease of incorporation and use by NASA has become extremely important.

Four critical ESS Project level milestones listed below pace the three year ESS Round-3 activity. Referred to subsequently as Project-Milestone-1, etc., they, along with their metrics and milestone achievement criteria, are in the NASA HPCC Program Plan and constitute the agreement between ESS and NASA Headquarters for the execution of Round-3. They are expanded to the 12 required Investigator Milestones in Appendix A.

Project-Milestone-1. Baseline Grand Challenge Earth and space sciences
model, assimilation, and data analysis codes   [October 2000]

Project-Milestone-2. Demonstrate Grand Challenge codes interoperating
within communities of related codes using
prototype frameworks   [October 2001]

Project-Milestone-3. Demonstrate significant scientific improvement of
Grand Challenge codes while conforming to
interoperation standards   [October 2002]

Project-Milestone-4. Show sustainable customer use of Grand Challenge
code components   [October 2003]

The ESS Grand Challenge Investigator Teams selected through this CAN serve as leading edge developers of high performance applications codes and aggressive users of leading edge scalable testbed systems and their software environments. They contribute significantly to the research synergism of the ESS Project that includes additional related elements including:

  • The applications support staff in the Teraflop/s Scalable Testbed vendor organization assisting the Investigator Teams to achieve code improvement milestones. The acquisition of the Teraflop/s Scalable Testbed is described in Appendix D;

- System software developers and applications support staff for the Commodity Based Testbed evolving and supporting clusters of PCs using the Linux operating system operated as high end computer systems for use and evaluation by Investigator Teams (Appendix D);

- GSFC and JPL Center based software engineers facilitating development of software frameworks for interoperability of application codes;

- GSFC and JPL Center based computer and computational scientists developing high performance computational plug-in application codes in support of various frameworks represented by Round-3 Investigations;

- ESS evaluation staff (approach is described in Appendix E) assisting Investigators to characterize their application codes and carry out performance and scaling measurements on the Testbeds;

- GSFC and JPL Center based staff developing applications middleware, high end visualization, and mass storage technologies;

- ESS and NREN staff developing and applying wide area networking technologies; and

- The Scientific Visualization Studio at GSFC developing visualization products for Investigator Teams.

3. Authority

This notice will result in cooperative agreements as defined in 31 U.S.C. 6305 (the Chiles Act) and is entered into pursuant to the authority of 42 U.S.C. 2451, et seq. (the Space Act).

4. Goals and Objectives of this CAN

A primary goal of the ESS Round-3 CAN is to achieve code interoperability through definition, adoption, and use of common software interfaces by communities of NASA modelers, allowing their codes to interoperate in common frameworks and to simultaneously achieve high performance. This goal applies equally to Earth Science and Space Science. Identification of the communities to be supported under this CAN will result from the proposal selection process.

Investigations are sought whose software products will be used by other groups, especially through an identifiable provider/customer relationship. Proposals should identify their customers, their deliverables, and the mechanism to be used to transfer the deliverables to the customers or into community assets.

The following Round-3 Investigator objectives derive from the goals. They link the Investigators, the Testbed teams, and the NASA inhouse computer and computational scientists:

(i)   Prepare high performance scalable parallel codes from Grand Challenge Investigations for broad use by the NASA Earth and space sciences research and flight program community;

(ii) Foster software interface agreements within key Earth and space sciences communities enabling interoperation of software components;

(iii) Achieve code interoperation and high performance simultaneously;

(iv) Fill community priority needs for portable code components compatible with agreed on software interfaces;

(v) Enable science communities to leverage code interoperation by testing, comparing, and using alternative code implementations; and

(vi) Facilitate spin-offs from Round-3 Investigations that benefit education, the public, or state and local governments.

5. Software Development Strategy

5.1 Need for increased Software Engineering emphasis in scientific codes

Software engineering seeks to provide software solutions, by design, having qualities including scalability, evolvability, dependability, usability, performance, and predictability of cost and schedule. Engineering documentation is integral for successful implementation of these qualities. Research in software engineering is ongoing. The best practices of a decade ago are often not accepted today.

ESS Round-3 Investigations are being sought that will engage science communities in the application of software engineering principles to the solution of their critical problems in high end computing, visible at the highest levels of NASA. These Investigations may involve legacy as well as developmental Earth and space sciences codes. This work will be carried out on two fronts:

1) Applied Software Engineering within Investigator Teams: ESS encourages the numerical packages developed in Round-3 to employ clear and specific software engineering methods. Desired results include proper structuring and documentation to support reuse, portability, and performance. An ambitious response would be to target Carnegie Mellon Maturity Model Level III; ESS expects that teams will achieve Level II [see Capability Maturity Model for Software at http://www.sei.cmu.edu/cmm/cmms/cmms.html].

2) Community based software frameworks: ESS will require Round-3 Teams to be engaged with other researchers within self defined scientific communities in evolving mutually beneficial application frameworks. ESS encourages use of existing frameworks for faster development and broader user base. If a new community framework is proposed, then this activity is expected to involve: joint community specification and construction of the framework with well defined interfaces, development of high performance high-level model plug-in code components compatible with the framework, and interoperation as a community.

By addressing the issues of software engineering and code interoperation now, a better environment for application development and reuse will be fostered both within NASA and within the overall Earth and space sciences research communities. A more detailed discussion of each of these two aspects follows.

5.1.1 Applied Software Engineering within Investigator Teams

Software engineering is a critical aspect for the design and maintenance of robust software products. For example, developers of large-scale commercial applications commonly make use of phased approaches. This involves applying milestones to requirements, detailing designs, conducting design reviews and code walk-throughs, and delivering the software incrementally. NASA recognizes that many existing numerical modeling codes were designed long ago and have evolved without the benefit of modern software engineering techniques. A

goal of the ESS Round-3 effort is to promote these important concepts to ongoing projects that develop and make use of large Earth and space science modeling codes. Some of the key concepts include:

  • Documenting requirements for the application
  • Developing and implementing a strategy for a phased approach to software development for
    the full lifecycle of the model and linking the strategy to requirements
  • Developing and implementing a Software Maintenance Plan
  • Developing and implementing a Validation Plan

ESS advocates principles of software engineering that have been part of past successful modeling projects:

  • Use of modular code with well-defined, adaptive, and flexible interfaces
  • Use of common frameworks to standardize interfaces and allow interoperability
  • Use of commercial off the shelf (COTS) tools to promote development of highly scalable
    code that is both portable and high performing
  • Use of standard tool kits to construct user interfaces that are intuitive without the need for
    significant documentation

Each proposal to the ESS Round-3 CAN will be required to have a software engineering plan that addresses the above issues. In particular, proposals should specify approaches to key points such as:

  • Design elements that enable ease-of-maintenance, and robust integration of experimental
    modules (maintenance and development may be geographically dispersed efforts).
    Flexibility, portability and performance are all important design goals.
  • Plans for open source, software reuse, and interoperability with other community efforts.
  • Plans for community engagement beyond delivery and receipt of comments.
  • Plans to collaborate with the Evaluation Team's efforts to instrument development codes.

5.1.2 Community based framework engagement

Many of the above design goals involve community commitments and cannot be achieved unilaterally by single groups. As a result, groups will have to commit to using or building frameworks with their research community.

Frameworks are still an emerging technique, but they have demonstrated their value in managing large software projects spread over multiple locations. Many groups have come to this approach in despair after multiple brushes with catastrophic failure. While first promoted in the context of reusability, they have become more popular as a mechanism to express open systems. Frameworks are typically defined as a reusable design for systems, disciplines or families of applications, just as an abstract class is a reusable design for a component.

Interoperation of codes gives advantage beyond just adding more components to systems of coupled models. It opens the way for accelerating evolution of the coupled model systems. Research groups whose models do not interoperate with those of other groups have to supply all of their own model components. Advances from other groups can only be incorporated by changing their own model codes to incorporate the new 'foreign' features that are considered desirable. This situation could clearly be made more efficient. Agreement on certain software interfaces has been shown to facilitate sharing of model components allowing groups to run model components developed by other groups, stimulating comparison and adoption. Stable interface standards also open up the potential of tapping an even wider range of new

intellectual capacity, notably algorithm developers who are not part of any of the major modeling groups, to contribute components that have broad impact.

A primary goal of the ESS Round-3 CAN is to achieve code interoperability through definition, adoption, and use of common software interfaces by communities of NASA modelers allowing their codes to interoperate in common frameworks, and to simultaneously achieve performance of individual codes operating in those frameworks. Appendix B provides a discussion of frameworks. Proposal pressure in response to this CAN will drive the determination as to who these communities are. This goal applies equally to Space Science and Earth Science.

NASA is investing in the Round-3 Grand Challenge Investigations with the goal of having broad impact in the scientific community. Investigations are sought whose code products will be used by other groups, especially through an identifiable provider/customer relationship. Proposals should identify their customers, their deliverables, and the mechanism to be used to transfer the deliverables to their customers or into community assets. All applications software developed under cooperative agreements must also be delivered to the ESS Project in documented source form for publication via the World Wide Web.

In particular, ESS has set an objective in Round-3 of facilitating movement of a critical mass of the NASA Earth system modeling community to a common modeling infrastructure, a step they have called for (see Appendix C), by actively facilitating the joint definition of an Earth System Modeling Framework (ESMF) by this community and migration of their codes to this framework. This CAN will be responsive to proposals submitted in support of this objective. The ESMF effort will be a collaboration among the winning Round-3 Investigator Teams proposing participation in it, and the ESS Project. In order for the ESMF activity to proceed, at least three high quality proposals who wish to participate must be selected. Participating ESMF Teams along with an ESS Project representative will be responsible for defining the framework. Teams will be responsible for implementing their applications within it. To facilitate this work, NASA will provide the services of a software engineering organization, termed the *ESMF Integrator*, to facilitate and support the development and implementation of the ESMF.   The Headquarters Selection Official will constitute the ESMF Science Team to oversee this activity from among proposers who have expressed an interest in being a part of the activity (see Appendix A).

5.2 Application Improvement

Each proposing Team must identify in its proposal the code or codes that it will be improving and making interoperate with other codes in a framework. Several Team milestones will state the nature of the improvement and have a quantified metric stating the degree of improvement. The metric for each software improvement milestone must be in units of quality valued by the NASA science community or flight projects. A partial list of possible science metrics is given here, but only to stimulate the thought processes of those writing proposals since it is they, and not ESS, who must identify quality metrics important to NASA science or mission success:

- Throughput
- Resolution
- Volume of mission required products produced
- Physical fidelity
- Time to solution
- Relaxation of physical simplifying assumptions
- Number/variety of data sets used for initialization, validation, or assimilation

- Number of experiments conducted per unit time
- Number of community codes interoperating under a framework
- Data volume handled per unit time
- Teraflop/s

The milestone achievement criteria for each metric must be stated, and it must be quantified. Milestone achievement criteria may be stated in absolute terms, or as improvement over baseline. Further discussion of code improvement metrics and milestone achievement criteria is found in section 2 of Appendix A.

6. Milestone Driven Agreements

6.1 Grand Challenge Investigator Teams

Candidate NASA Grand Challenge application domains are found in the Strategic Plans of the Earth and Space Science Enterprises as well as in the Life & Microgravity components in the Strategic Plan of the Human Exploration and Development of Space Enterprise (see Appendix F). Many require the integration and execution of multiple advanced disciplinary models into single multidisciplinary applications. Examples of these include coupled oceanic-atmospheric-biospheric interactions, 3-D simulations of the chemically perturbed atmosphere, solid Earth modeling, solar flare modeling, and space weather modeling. Others are concerned with analysis and assimilation into models of massive data sets taken by spaceborne sensors in the areas of global warming and ozone depletion on Earth, and planetary science and astronomy. These problems are significant in that they have both social and political implications in our society. The science requirements inherent in the NASA Grand Challenge applications necessitate computing performance in the teraflop/s range.

Candidate ESS Investigator Teams may be composed of individuals from academia, industry, NASA Centers, or other government agencies. Each team must be led by a single Principal Investigator who is empowered to represent the team in all administrative matters, including negotiations. Co-Investigators with accountable team roles may and should be identified in the proposal. However, NASA will sign an agreement with only the Principal Investigator's institution. It is the Principal Investigator's responsibility to manage the team, negotiate agreements among team members, and arrange for dispersal of funds after milestones are achieved. The Principal Investigator is expected to spend, at a minimum, approximately 1/3 of his/her time on this project (research, management, administration).

Each team must propose to meet Required Investigator Milestones listed in Section 1 of Appendix A and may propose to meet up to two of the Optional Investigator Milestones listed in Section 4 of Appendix A. These milestones will be negotiated into the Cooperative Agreements of the selected Investigators. Investigators are expected to achieve these milestones by using the Testbeds provided by ESS (described in Appendix D), although they are free to use other systems to which they acquire access. Note that because the ESS Project mandates aggressive performance milestones, this CAN targets scientists currently using parallel systems. Specifically, Investigator Teams must demonstrate experience in using scalable parallel processors, in measuring performance, and in performing software engineering. See Appendix A for details.

A "Science Team III", comprising the Principal Investigators selected for award under this CAN and a Project Scientist who will be elected from among the Principal Investigators, will be convened by the ESS Project and will operate during the three year award period. This group will augment the work of "Science Team II", which is composed of the ESS Grand

Challenge Investigators selected under the 1995 NASA Cooperative Agreement Notice (CAN-21425/041). Information about the Science Team II Investigators and their work can be browsed at http://esdcd.gsfc.nasa.gov/ESS/investigators.html.

Science Team III (hereafter referred to as the "Science Team") will contribute to the evaluation of the testbed architectures and the software environments that are part of the NASA HPCC Program. In particular, the Science Team will provide direct and frequent feedback to NASA and the Teraflop/s Scalable Testbed vendor to highlight Testbed strengths and weaknesses and to streamline the process of identification and correction of system deficiencies. It is expected that all PIs will participate in Science Team meetings, will be represented at computational techniques and evaluation workshops, and will contribute to Science Team reports. Each of these activities will occur at a maximum of twice annually, and each team should plan to send one representative to each. At the conclusion of Round-3, the Science Team members will jointly prepare findings and recommendations to NASA concerning future research directions in high performance computing software and acquisitions of scalable computing systems.

6.2 Required Investigator Milestones

ESS will manage the Round-3 Investigator Teams through payments made for achievement of negotiated milestones. Each signed Cooperative Agreement will contain at least 12 negotiated milestones as listed and described in Sections 1 through 3 of Appendix A. Each milestone will include an accomplishment or deliverable, its value in dollars and its expected date of achievement. It is expected that the accomplishment or deliverable for many of the milestones will be team specific. When a team achieves a milestone, it documents the achievement and submits it to the ESS Project for validation and payment.

6.3 Optional Investigator Milestones

There are a number of research activities taking place within ESS and the broader NASA HPCC Program that can benefit greatly by partnering with Grand Challenge Teams as technology customers. Descriptions of these activities are found in Section 4 of Appendix A. Teams proposing to Round-3 are asked to study these descriptions and propose one or two collaborative activities that would be of significant scientific value to the proposing Team. ESS may negotiate up to two optional milestones into some signed Cooperative Agreements. Proposals do not need to propose any optional milestones but ESS hopes that they will.

7. Availability of Funds

Funding for the resultant Cooperative Agreements is currently in the President's budget request for NASA. However, funding for FY 2000 and subsequent years is dependent on the availability of funds appropriated by the U.S. Congress, and therefore this funding is not presently available. The Government's obligation under this cooperative agreement notice is contingent upon the availability of appropriated funds from which payment for cooperative agreement purposes can be made. No legal liability on the part of the Government for any payment may arise until funds are made available to the Contracting Officer for this cooperative agreement and until the recipients receive notice of such availability, to be confirmed in writing by the Contracting Officer.

8. Cancellation of CAN

NASA reserves the right to make no awards under this CAN and, in the absence of program funding or for any other reason, to cancel this CAN by having a notice published in the Commerce Business Daily. NASA assumes no liability for canceling the CAN or for anyone's failure to receive actual notice of cancellation. Cancellation may be followed by issuance and synopsis of a revised CAN, since amendment of the CAN is normally not permitted.

9. Withdrawal

Proposals may be withdrawn by the proposer at any time. Offerors are requested to notify NASA if the proposal is funded by another organization or other changed circumstances which dictate termination of evaluation. A proposal funded by another organization must be withdrawn by an offeror.

10. Foreign Participation

Companies or business entities that are directly or indirectly controlled by a foreign company or government are ineligible for participation under this CAN unless:

• Such foreign companies or government permits and encourage United States agencies, organization, or persons to enter into cooperative research and development agreements and licensing arrangements on a comparable basis;

• Those foreign governments have policies that protect the United States intellectual property rights; and

• Those foreign governments have adopted adequate measures to prevent the transfer of strategic technology to destinations prohibited under national security export control laws of the United States through appropriate international agreements to which the United States and such foreign governments are signatories.

• Any subawards or subcontracts for foreign research efforts (not included routine supplies or services procurements) awarded by the recipient must be performed on a no-exchange of funds basis.

All work or research performed under a cooperative agreement resulting from this CAN must be performed within the United States. Proposals including work or research that will be performed outside of the United States, in whole or in part, are not acceptable and will not be given further consideration for award.

11. Small Business and Minority Institution Participation

Small business, small disadvantaged business and women-owned small business concerns, as well as, historically black colleges and universities (HBCUs) and other minority institutions are encouraged to participate in this CAN.

12. Schedule

The schedule for the review and selection of HPCC/ESS CAN proposals is as follows:

tbd	Release of the CAN
tbd	Preproposal Conference
tbd	Letter of Intent to Submit Proposal due
tbd	Proposals due

tbd   Announcement of selections for negotiation
tbd   Announcement of award (target date)
tbd   Funding of award(s)

APPENDIX A

Required Milestones and Optional Milestones

A.1 Required Investigator Milestones

Section 6.2 overviewed the required Investigator milestones. This appendix lists these milestones, describes them, and shows the format for Teams to propose them. ESS will manage the Round-3 Investigator Teams through payments made for achievement of negotiated milestones. Each signed Cooperative Agreement will contain at least 12 required milestones. Each milestone will consist of an accomplishment or deliverable, its value in dollars, and its expected date of achievement. Some milestones also need quantified metrics. Since each Team is unique, it is expected that the exact accomplishment or deliverable for many of the milestones will be team specific. The exact wording and value of each team specific milestone will be finalized by negotiation. When a team achieves a milestone, it documents the achievement and submits it to the ESS Project for validation by the Inhouse Team. When ESS management determines that the milestone has been achieved, an electronic funds transfer is made to the Principal Investigator's Institution. This is the only way that funds are transferred to a Team, and milestones will not be paid out of order. This CAN will not result in award of a cost reimbursable contract. Figure-1 shows the 12 milestones which prospective Round-3 Teams are asked to propose.
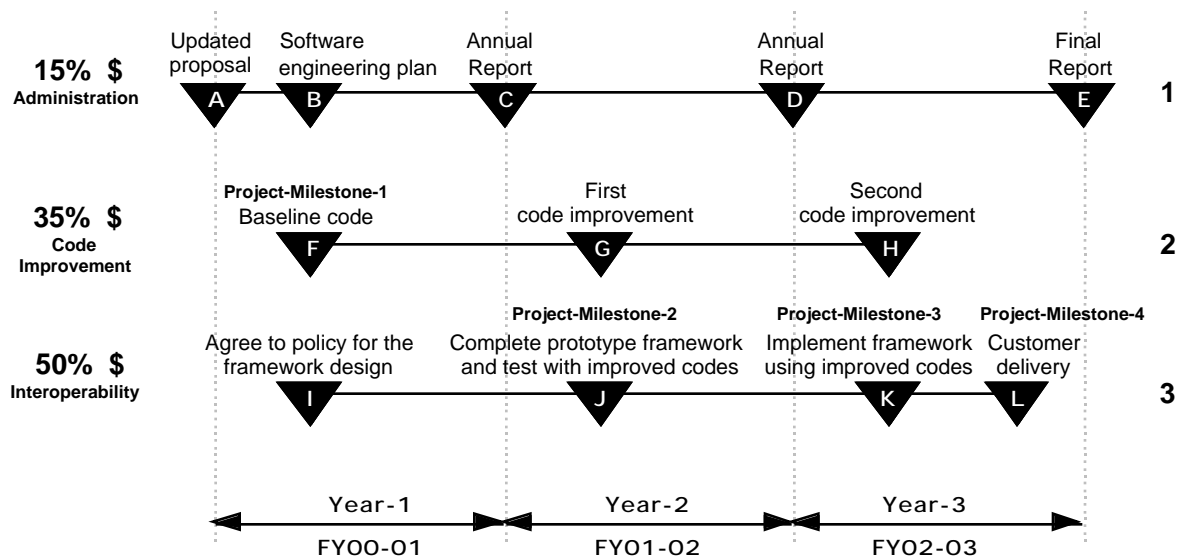

Figure-1, Each proposal must include these 12 milestones.

The 12 milestones in Figure-1 are grouped by line into three categories. The total payments requested for milestones in each category should roughly sum to the percentage indicated at the left margin of the total funds requested.

The first set of milestones are administrative in nature:

A) Completion of negotiations and execution of the cooperative agreement. NASA pays for an updated proposal consistent with the result of negotiations. This provides initial cash flow to the teams.

B) Software engineering plan: validates that a suitable software engineering infrastructure exists within the Investigator Team necessary to carry out the large scale, multi-code, and possibly multi-site, software development effort proposed. It is the responsibility of the proposer to identify the software engineering needs of their Team and the means for implementation; a general discussion of the issues is found in Section 5.1.

C) Annual report — delivered as a web page following a format template provided by NASA in the sample Cooperative Agreement [see examples of annual reports from ESS Round-2 Investigators at http://esdcd.gsfc.nasa.gov/ESS/annual.reports/ess98/ess98.html].

D) Annual report — delivered as a web page following a format template provided by NASA.

E) Final report — delivered as a web page following a format template provided by NASA.

The second set of milestones focuses on code improvement: The metric for the baseline and the code improvements will be science related as discussed in Section 5.2. Section 2 of Appendix A explains the possible need for an additional performance metric.

F) Baseline code: Teams establish the current baseline performance of the code or codes identified in the proposal to be improved on the ESS Teraflop/s Scalable Testbed. Improvements to be met in milestones G and H are negotiated relative to this baseline. Documented code developed to achieve this milestone is placed on the web.

G) First code improvement milestone: This milestone sets an intermediate level of code improvement over the baseline. Documented code developed to achieve this milestone is placed on the web.

H) Second code improvement milestone: This milestone sets the final level of code improvement over the baseline. Documented code developed to achieve this milestone is placed on the web.

The third set of milestones focuses on framework implementation and use.
If milestones I, J, and K involve the construction of a new framework, proposed milestone values may need to include payments to some framework community members to support their effort to collaborate on the framework development. If milestones I, J, and K involve implementing codes within an existing framework, proposed milestones should be valued accordingly.

I) Agree to policy for the framework design: Teams must identify either an existing community framework that they will use for code interoperation with other community member codes or the community with which they propose to facilitate creation of a community framework. In the former case, they must deliver via the web a public definition of the framework in sufficient depth and thoroughness that other community members can write code that interfaces to it and use it productively. In the latter case Teams must collaborate with the other members of their framework community to come to agreement on draft framework interfaces with sufficient depth and thoroughness that the other community members could write code which interfaces to it. This framework interface definition must be delivered via the web. The Earth System Modeling Framework (ESMF) is an instance of the latter case.

J) Test improved code with prototype framework: Once the definition of the framework interfaces is agreed to, a prototype framework is constructed with the continuous involvement of technical staff from each member of the framework community. In the case of the ESMF, this activity is facilitated by the ESMF Integrator. The community then tests

the prototype framework using their codes and evaluates the result. The framework source code must be delivered via the web.

K) Implement improved code to framework: Assuming that the prototype framework is found during testing to have significant shortcomings, then a rework of the framework is carried out with the continuous involvement of technical staff from each member of the framework community. In the case of the ESMF, this activity is facilitated by the ESMF Integrator. The community then begins to use the framework with their science codes. The framework source code must be delivered via the web.

L) Customer delivery: Taking advantage of the newly achieved interoperability, components of each Team's code are shown to be used by another team within their framework community. Portability of this framework is also demonstrated by moving the framework to a different architecture.

A.2 Metrics for Baseline and Code Improvement Milestones

The metric for each Round-3 milestone related to code improvement (milestones F, G, and H) must be in units of quality valued by the NASA science community or flight projects. A partial list of possible metrics is given in Section 5.2. The milestone achievement criteria for each of these metrics must be stated and quantified (see Figure-2). Milestone achievement criteria may be stated in absolute terms, or as improvement over baseline.

Statement of milestone	**Science metric** (in units of quality valued by the NASA science community or flight projects) ... **Milestone achievement criteria** (quantified in absolute terms or improvement over baseline) ...

Figure-2, Code improvement milestones must include
a science metric with quantified milestone achievement criteria.

In the last round of ESS investigations, primary optimization support for the Grand Challenge Investigations was provided by the Testbed vendor, and the resulting benefit to the Investigations was outstanding. Several aspects of the arrangement between the Investigations and the Testbed vendor led to success, a key one being the existence of several negotiated performance milestones for each Investigator Team that identified an existing code and set quantified performance expectations for all parties. This empowered the Testbed vendor's applications support staff to formulate their technical approach in concert with the technical staff of each Investigator Team, who had the same goal. ESS plans to make available an equivalent approach in Round-3.

Therefore, even though the milestone achievement criteria of Round-3 Investigator Teams will be in units of quality valued by the science community, for Teams to receive substantive assistance from the applications support team provided by the Teraflop/s Scalable Testbed

vendor, the metrics for software improvement milestones must also be expressed in terms of performance. A partial list of possible performance metrics is given here.

- Throughput
- Volume of mission required products produced
- Time to solution
- Number of experiments conducted per unit time
- Data volume handled per unit time
- Teraflop/s

Therefore, if the science metric for milestones F, G, and H is not quantified in terms of performance, proposals are asked to include an additional comparable performance metric with quantified milestone achievement criteria as shown in Figure-3. The milestone achievement criteria for each metric must be stated and quantified. Milestone achievement criteria may be stated in absolute terms, or as improvement over baseline. Figure-4 shows an example.

| Statement of milestone

... | Science metric
(in units of quality valued by the NASA science community or flight projects)
...

Milestone achievement criteria
(quantified in absolute terms or improvement over baseline)
... | Comparable performance metric
(only needed if the science metric is not expressed in terms of performance)
...

Milestone achievement criteria
(quantified in absolute terms or improvement over baseline)
... |
|---|---|---|

*Figure-3, Code improvement milestones also need a comparable performance
metric with quantified milestone achievement criteria if the science
metric is not quantified in terms of performance.*

| Statement of milestone – G

Improve MUDSLIDE3D resolution by 5x over baseline with same time to solution. | Science metric
(in units of quality valued by the NASA science community or flight projects)
Resolution of simulation in meters

Milestone achievement criteria
(quantified in absolute terms or improvement over baseline)
5x | Comparable performance metric
(only needed if the science metric is not expressed in terms of performance)
Time to solution

Milestone achievement criteria
(quantified in absolute terms or improvement over baseline)
Same time to solution as baseline |
|---|---|---|

*Figure-4, Example of improvement milestone G with a science metric
(not quantified in terms of performance) and a comparable performance metric
(with quantified achievement criteria)*

A.3 Required Investigator Milestones as would appear in proposal

Proposals must include a list of proposed milestones in a format similar to that shown below. The list should include the 12 Required Investigator Milestones as described in Section A.1.

Milestone	Due date	Value
A. Update proposal	<date>	<$>

Example: Deliver update of proposal including negotiated milestones, quantified metrics, and milestone achievement criteria.

Milestone	Due date	Value
B. Software Engineering Plan	<date>	<$>

Example: Deliver software engineering plan describing software engineering infrastructure within the Investigator Team. *[This is an update of the software engineering plan in the proposal responding to issues raised during negotiations.]*

Milestone	Due date	Value
F. Baseline code (Project-Milestone-1)	Oct. 2000	<$>

Baseline <name of code or codes> using <state quantified science metric> <and state additional quantified performance metric if needed>. Provide code scaling curves. Deliver documented version of code used to achieve this Milestone on the web.

Example: Baseline MUDSLIDE3D at maximum resolution on ESS Testbed for Mt. St. Helens event demonstrating at least 15% of peak machine performance. Provide code scaling curves demonstrating at least P/2 scaling to 256 processors; deliver documented source code via the web. Deliver specification of the physical problem being simulated.

Milestone	Due date	Value
I. Come to agreement on policy for the framework design	<date>	<$>

Deliver agreement on definition for <identify framework> with <identify community members> and publish on the web.

Example: Declare that existing QUAGMIRE Framework will be used to implement MUDSLIDE3D++. <Specify working relationship with QUAGMIRE team.> <Specify power users outside of MUDSLIDE3D++ and QUAGMIRE teams who will provide feedback for design.>

Example: Define and deliver document for new QUICKSAND2 Framework for MUDSLIDE3D++ to be developed for Milestone J. <Identify community members who will use the framework and mechanism for feedback to the developers.>

Milestone	Due date	Value
C. Annual Report	Aug. 2001	<$>

Example: Submit FY01 Annual Report to ESS via web.

Milestone	Due date	Value
G. First code improvement	<date>	<$>

Improve <name of code or codes> to <state milestone achievement criteria in terms of quantified science metric> <and

*state additional milestone achievement criteria in terms of
quantified performance metric if needed>. Provide code scaling
curves. Deliver documented version of code used to achieve this
Milestone on the web.*

Example: Improve MUDSLIDE3D++ resolution by 5x over
baseline with same time to solution. Provide code scaling curves
and deliver documented source code via the web.

J. Complete prototype framework and test with improved codes
   (Project-Milestone-2)   Oct. 2001   <$>

*Implement and test improved version of <name of code or
codes> with prototype of <identify framework>. Deliver
framework source code via the web.*

Example: Demonstrate improved MUDSLIDE3D++ in
QUICKSAND Framework using ROCK2D subgrid physics.
Deliver documented QUICKSAND Framework source code via
the web.

D. Annual Report   Aug. 2002   <$>

Example: Submit FY02 Annual Report to ESS via web. *[Include
achievements from use of the released code by community.]*

H. Second code improvement   <date>   <$>

*Improve <name of code or codes> to <state milestone
achievement criteria in terms of quantified science metric>
<and state additional milestone achievement criteria in terms of
quantified performance metric if needed>. Provide code scaling
curves. Deliver documented version of code used to achieve this
Milestone on the web.*

Example: Improve MUDSLIDE3D++ resolution by 15x over
baseline with same time to solution. Provide code scaling curves
and deliver documented source code via the web.

K. Implement framework using improved codes (Project-Milestone-3) Oct. 2002   <$>

*Implement improved version of <name of code or codes> with
improved version of <identify framework>. Deliver framework
source code via the web.*

Example: Demonstrate full interoperability of
MUDSLIDE3D++, ROCK2D, MUCK7 and FELLDOWN
within QUICKSAND2 Framework. Deliver documented
QUICKSAND2 Framework source code via the web.

L. Customer delivery (Project-Milestone-4)   March 2003   <$>

Achieve sustainable customer use of <name of code or codes>.

Example: Port the QUICKSAND2 Framework to a different
architecture than the Teraflop/s Scalable Testbed within 2 work
weeks and demonstrate its operation. Deliver the

QUICKSAND2 Framework and components to geology groups
at university x, y and z.

E. Final Report   <date>   <$>

Example: Submit Final Report to ESS via the web.

A.4 Optional Investigator Milestones

This appendix describes a number of research activities that would benefit from partnering with Grand Challenge Teams as technology customers. The Center based portions of the ESS Project at GSFC and JPL reside within research and production computing organizations that primarily support the missions of the Earth and Space Science Enterprises. These organizations are assisted by ESS in seeding their long range capabilities by strategic insertion of leading edge technologies, making them, in turn, better able to support ESS Investigations and their other customers with production computing services. To help them direct their research investments, it is of great benefit to these organizations to identify and carry out joint research projects with Grand Challenge Teams as technology customers. ESS wishes to use this Round-3 CAN as a means to identify candidate joint projects and then to negotiate some projects into paid milestones with selected teams. The complementary Center based group at GSFC, JPL, or ARC participating in the collaboration would have the same milestone.

Teams proposing to Round-3 are asked to study the descriptions provided below, including referenced web sites, and propose one or two collaborative activities that would be of significant scientific value to them. Sufficient descriptive text should accompany the proposed milestone to enable the ESS group identified in the collaboration to be able to understand the proposed goal, assess the benefits to their work, estimate the resources that they would need to invest, and anticipate the time schedule. Proposers selected for negotiations will be asked to engage in a dialogue with the ESS group identified and some of these dialogues will result in mutual agreement and the inclusion of optional milestones in signed Cooperative Agreements. Each proposed optional milestone needs a dollar value and a due date. It is not mandatory that Grand Challenge proposals include optional milestones, but it is hoped that signed Cooperative Agreements will contain between one and two optional milestones having a value between 10% and 20% of the total value of the required milestones.

a) Parallel Adaptive Mesh Refinement package augmentation

Adaptive mesh refinement (AMR) is an advanced numerical technique increasingly popular in the scientific and engineering communities for Grand Challenge scale applications which cannot achieve the spatial resolution they require with uniform grids. Use of AMR techniques can significantly improve computational and computer memory efficiency by devoting finite CPU and memory resources to computational regions where they are most needed, thus making it possible to compute an accurate numerical solution with much less computing resources compared to using a global fine mesh. AMR algorithms and software development for uniprocessor computers have been investigated for many years, and successful applications of AMR techniques have been reported in the literature. Development of parallel AMR algorithms and software tools, however, is still a relatively new research area. The web page http://esdcd.gsfc.nasa.gov/ESS/amr.html describes two AMR packages being developed by ESS. Round-3 proposals are invited to propose to augment or use-as-is one or both of these packages to achieve a key milestone.

b) Visualization research

The Scientific Visualization Studio (SVS) at GSFC [http://svs.gsfc.nasa.gov/] is interested in collaborating with some Round-3 Teams to push specific research fronts. A list of SVS research topics is provided here to spark interest from proposing Investigators.

• Distributive visualization
• Collaborative visualization
• Virtual environments (direct manipulation, 3-D, haptic, data sonification)
• Visualizing very large data (>100GB)
• High quality (non-interactive) visualization
• Visualization in real-time (during simulation)
• Parallel-based visualizations
• Visualization of unique data structures (e.g., adaptive mesh)
• Technology driven topics:
   Gigawalls, CAVEs
   Mini-CAVE (LAIR)
   HDTV
   low-end visualizations on PCs/Linux/laptops

c) Mass storage research

Some Round-3 ESS Grand Challenges will be more constrained by their data intensive nature than their compute requirements. Increasing data intensive trends are being forecast by the NCCS and the JPL Computing Center where Round-3 codes or their derivatives may run in production mode in future years. These and other high end computing centers find themselves frequently carrying out path breaking activities in mass storage because of the leading edge capacity and performance requirements of their customers. The computing environment of the Teraflop/s Scalable Testbed, which will be shared by several other high end projects, as well as the Commodity Based Testbed, are appropriate locations to carry out research in leading edge mass storage. Currently, the NCCS...unitree...big... Currently ESS is conducting research in inexpensive commodity based mass storage servers [URLs: http://beowulf.gsfc.nasa.gov, and http://ece.clemson.edu/parl/pvfs]. Proposals of collaboration are invited in the following areas:

• Data mining
• Path finding tertiary storage expansion
• Commodity based mass storage servers using Linux

d) Networking research

The NASA Research and Education Network (NREN) Next Generation Internet (NGI) Project at NASA ARC is cooperating with the Earth and Space Science (ESS) Project to support the development and prototyping of NGI/ESS networking research and applications. Projects proposed for a "Networking Research" optional investigator milestone should be aiming to push the envelope of distributed science computation and visualization over high performance research and education networks (HPRENs). Such networking research activities as distributed "middleware" for security or multicast, or provision and measurement of end-to-end quality of service (QoS), at very high speeds over multiple HPRENs, would be especially interesting. The networks involved would be one or more of the NGI "JETnets" -- NREN, NISN, Abilene, vBNS, ESnet, DREN -- or the DARPA SUPERNET networks (e.g., NTON, MONET, OnRamp).

NREN	http://www.nren.nasa.gov
NISN	http://www.nisn.nasa.gov/
Abilene	http://www.internet2.edu/abilene/
vBNS	http://www.vbns.net/
ESnet	http://www.es.net/

DREN	http://www.hpcmo.hpc.mil/Htdocs/DREN/
ATDnet	http://www.atd.net/
SuperNet	http://www.ngi-supernet.org/
NTON	http://www.ntonc.org/

New Next Generation Internets such as the DARPA-funded SuperNet testbeds and the Internet2-funded Abilene network currently are being deployed nationwide at 2.4 Gbps in each of one-to-eight optical wave division multiplex (WDM) channels. For the last four years GSFC has participated actively in the Advanced Technology Demonstration Network (ATDNet) which DARPA now has upgraded to a SuperNet with 2.4-to-10 Gbps in eight channel WDM networking elements from the (Multiwavelength Optical Network (MONET) Consortium and has interconnected at 2.4 Gbps to the other SuperNets. This connection enables the computers and data of new Earth and Space Science Enterprise programs involving GSFC such as the Digital Earth, HPCC/ESS Round 3 Testbed, and Digital Sky to be accessed at effective end user data rates greater than 1 Gbps. However, network application users typically do not obtain such high effective end user data rates because either their applications are not "network tuned" or their host computers are not working with more modern network protocols. In Round-3, ESS will encourage Investigators to tune their applications to perform well over the high speed networks available and to assist with research which improves either the network protocols or the software interfaces between their application level programs through their host computer's operating system to their computer's network interfaces.

To encourage use of clusters of inexpensive PCs – In Round-3, ESS will encourage Investigator use of clusters of inexpensive PCs for Grand Challenge code development and performance runs, in particular the Linux based approach [http://beowulf.gsfc.nasa.gov/]. ESS sees the *pile of PCs* approach to high end computing as complementary to traditional proprietary vendor supplied high end systems and expects that some, but not all, Round-3 applications can be modified to effectively exploit this technology. Hence, ESS expects that Linux clusters will eventually supply a significant percentage of the computational resources required for Agency research and mission support.

e) Installation of a Linux cluster at an Investigator's home site

Several ESS Round-2 Investigator Teams have installed Linux clusters at their home sites and reported their beneficial local use, including debugging of scalable codes destined for running on more powerful remote centralized systems and as a source of inexpensive cycles by enabling dedicated use. ESS is receptive to the inclusion in Round-3 proposals of a milestone to install a Linux cluster at an Investigator site. ESS can assist with specifying the system but would not expect to contribute significant technical support to the Investigator's institution during construction or operation since commercial organizations now exist which provide these services. ESS plans to hold a tutorial/workshop after award to present approaches for achieving compatibility between the Investigator clusters and the GSFC resident clusters. The value of this milestone is capped at $100K.

f) Achievement of a code improvement milestone on a Linux cluster

ESS is interested in some Teams performing comparative studies of a code or codes that runs on two or more different systems and does the same job. Teams are encouraged to propose achievement of code improvement milestones G or H on a large Linux cluster and the Teraflop/s Scalable Testbed and documenting the work with a comparative study. ESS has integrated several generations of increasingly more capable Linux systems at GSFC since 1994 [http://beowulf.gsfc.nasa.gov] and plans to integrate several more during the period of Round-3. These systems will be assembled and made available to Investigator Teams. They

will typically incorporate 256-512 current generation PC processors. Specifics of their size and characteristics will be influenced by negotiated Investigator milestones requiring their use. The value of this milestone should be commensurate with the amount of code development required.

To assist spin-offs of ESS technologies – ESS is interested in seeing the research output of Investigator Teams matured to the point that it can benefit communities well removed from the NASA Earth and Space Science research world.

g) Outreach

Grand Challenge Teams may propose efficient ways for making materials or knowledge coming out of their Investigations available to the public or for use in primary and secondary education (K-12) in the U.S. For educational outreach, close collaboration with existing highly regarded organizations who regularly provide curriculum or supplementary materials to the education market is necessary in order to ensure conformance with the norms and standards of that community and to perpetuate the contribution.

h) Broader Technology Transfer and Access (Applications)

Grand Challenge Teams may propose ways for making problem solving approaches, algorithms, modules or data products coming out of their Investigations useful to public organizations such as state and local governments or private industry. Applications may take the form of products or services and may fall into the category of commercialization.

A.5 Optional Investigator Milestones as would appear in proposal

Proposals may include up to two optional milestones as described in Section 4 of Appendix A in a format similar to that shown below.

Milestone	Due date	Value
a) Parallel Adaptive Mesh Refinement (AMR) package use or augmentation *[specific collaboration with GSFC or JPL to use or augment a Parallel Adaptive Mesh Refinement (AMR) package]* Example: Merge PARAMESH (Parallel Adaptive Mesh Refinement Package) into QUICKSAND2 Framework. Supply sample adaptive MUDSLIDE3D++ simulation with performance and scaling curves.	< date>	[$]
b) Visualization research *[specific collaboration with GSFC or JPL to use or augment visualization or parallel visualization capabilities]* Example: Incorporate Immersadesk drivers into WATCHITSLIDE modules of QUICKSAND2 Framework. Deliver demo for SC02 conference.	< date>	[$]
c) Mass storage research *[specific collaboration with NCCS at GSFC to develop augmented high performance mass storage capabilities]*	< date>	[$]

Example: Install [specific] parallel I/O package on Linux cluster at Palisades University. Deliver performance and scaling for SAR processing compared with MUDSLIDE3D++ simulations.

d) Networking research   < date>   [$]
[specific collaboration with NREN/ARC or Advanced Networking/GSFC to use or augment high performance wide area networking capabilities]

Example: Using <specify Legion, Globus, etc.> capabilities in QUICKSAND2 Framework run MUDSLIDE3D++ distributed over computers at JPL and GSFC.

e) Installation of a Linux cluster at an Investigator's home site   < date>   [$]
[Install and make operational at an Investigator site a Linux cluster for code development and testing] [value constrained to $100K]

Example: Install 32 processor Linux cluster at Palisades University. Demonstrate MUDSLIDE3D running on the cluster.

Example: Install a 16-node (32-processor) Linux cluster at university x. The system characteristics will be: 450 MHz Pentium-IIIs, 256 MB RAM, 13 GB IDE disks and channel bonded switched fast ethernet, or better (depending on price/performance recommendations from ESS at the time of purchase). The system will be installed with a configuration that is consistent with the Linux clusters at GSFC as specified in the Beowulf administrator's tutorial given by ESS.

f) Achievement of a code improvement milestone on a Linux cluster   < date>   [$]
[Achieve either milestone G or H on the Teraflop/s Scalable Testbed and a Beowulf system to be provided by ESS - subject to agreement by ESS to provide the needed system. Provide a comparative analysis.]

Example: Demonstrate price/performance improvement of at least a factor of 9 for MUDSLIDE3D running on a Linux cluster compared to execution on the Teraflop/s Scalable Testbed.

Example: Port to a Linux cluster and evaluate the performance based on milestone G and H of MUDSLIDE3D without algorithmic modification. Work with the in house evaluation team to identify system characteristics that enhance or impede the cost effective use of cluster computing.

Example: Using the framework developed for QUICKSAND2, replace the communication intensive module MUCK7 with an approximation scheme AMUCK. Evaluate the impact on overall fidelity of QUICKSAND2 and its utility to its NASA mission compared to raw runtime and cost/performance of running on a cluster.

g) Outreach   < date>   [$]
[approach to make materials or knowledge coming out of Round-3 Investigations available to the public or for use in primary and

secondary education] [consider: Opportunities will exist to apply
for small educational supplements up to $5,000 to support
special projects.]

Example: Publish two popular articles on MUDSLIDE3D++.

Example: Work with Projectto deliver educational modules that
use MUDSLIDE3D++ to animate the physical processes
involved in the Mount St. Helens detonation. Enable students to
explore possible mudslides in the Mt. Rainier area demonstrating
impacts on existing population centers.

Example: Work with Channel 712 [Check this channel
number.]in Seattle to animate past and possible future mudslides
caused by regional volcanoes.

[Omar, please help with these examples]

h) Broader Technology Transfer and Access (Applications)   < date>   [$]
   [approach to make problem solving approaches, algorithms,
   modules or data products coming out of Round-3 Investigations
   useful to public organizations such as state and local
   governments or private industry]

Example: Work with <specify project lead> at FEMA to provide
a version of MUDLSIDE3D++ within QUICKSAND2 that could
be used for planning evacuations from a Mt. Rainier event.
Insure that user interfaces are sufficient to support FEMA
planners.

Example: Work with <specify project lead> in the Dept. of Civil
Engineering to apply MUDSLIDE3D++ to problems of stability
of concrete bridge footings in the Hood Canal Floating Bridge.

Example: Work with <project lead> in the State Department of
Natural History to simulate evolution of La Brea Tar Pits using
MUDLSIDE3D++.

[Omar, please help with these examples]

APPENDIX B
Frameworks for Earth and Space Sciences Applications

There is a wealth of literature that can help Teams judge and/or build frameworks. Frameworks trace their early history to the GUI technologies built using Smalltalk. However, they now appear in many domains. The Taligent Introduction to Building Object Oriented Frameworks provides four important guidelines:
  • Derive frameworks from existing problems and solutions
  • Develop small, focused frameworks
  • Build frameworks using an iterative process driven by client participation and prototyping
  • Treat frameworks as products by providing documentation and support, and by planning for distribution and maintenance

Ralph Johnson defines an object-oriented framework as having two essential parts:
  • A reusable design expressed as a set of abstract classes.
  • A description of how instances of those classes collaborate.

A framework is a set of prefabricated software building blocks that programmers can use, extend, or customize for specific computing solutions. With frameworks, software developers don't have to start from scratch each time they write an application. Frameworks are built from a collection of objects, so both the design and code of a framework may be reused.

In the language of object oriented programming, a framework is a set of related classes that can be specialized and/or instantiated to build an application. In thinking of a framework as a class library, you must be aware that the flow of control is bi-directional. An operation may well be defined within a library class, but its implementation can lie within the subclass that is in the user's application. In this way, the framework is not just a class library, but a design that can be reused to save time and effort. Both the design of function/control structure and the utility of the class libraries are critical to the success of a framework.

These features beyond mere class libraries give frameworks their power, but they also show their potential drawbacks. Like a new computer language, a framework has a learning curve. It requires considerable scrutiny to understand its design and efficient use for developing applications. The most difficult aspect of learning to use frameworks is understanding how they turn "procedural driven programming" on its head. Frameworks follow a principle "Don't call us, we'll call you". Control rests in the framework, with the application providing modules. This is the reverse of the programmer writing MAIN and calling library modules.

Like computer languages, one should be cautious about introducing a new one unless there is a critical niche to fill. Another analogy might be the physics underlying a Team's scientific applications. When a Team is developing an entirely new framework for problem solving, it should feel nearly as far out on a limb as if it were "building a new physics" to solve problems. If such a Team isn't extremely careful, the danger is that it will become a fringe player. In building frameworks for problem solving, it is important to develop experience using other frameworks to understand their structure. One should examine the available frameworks and try to extend them rather than build a new one. The ESMF project intends to start by examining other community frameworks with the hope that one will prove flexible and extensible enough to provide a basis for the final ESMF. At the very least, existing frameworks will be carefully

examined to see how their structure solves as well as creates problems for application developers.

In reviewing a number of frameworks, two features have emerged:
 • Good design is not a committee effort
 • Beware of being path breaking in ways that will become routine [i.e., developing a unique solution when a community supported general solution will exist]

The frameworks with clean designs were normally the efforts of a small set of people that grew to become a community effort. The most common failures of frameworks have been to invent new languages for scripting (rather than using C++) or to achieve an important goal such as implementing web aware clients before the advent of Java.

In the context of the move to massively parallel machines, compilers have fundamental problems providing the performance that is needed. Code produced by a compiler must be "nearly bulletproof". In a parallel code, this would mean that 99% of the machine's effort would be spent protecting the user by running a variety of run-time condition checking. To achieve performance without extreme effort, we need effective "middleware." Within a framework, the prefabricated building blocks have a lower level of optimized performance. The user is responsible for using the blocks as they were designed, eliminating the vast overhead that would be created by leaving this to the compiler.

A brief annotated bibliography:
 • Taligent has been absorbed into IBM. Some of their white papers and a bit of their product information can be found at
   http://www-4.ibm.com/software/ad/taligent/.
   Taligent Developers Resources can be found at the unlikely looking site:
   http://hpsalo.cern.ch/TaligentDocs/TaligentOnline/DocumentRoot/1.0/Home/index
   Taligent Documented Sample Code resides at:
   http://hpsalo.cern.ch/TaligentSamples/HTMLDocFiles/index

 • ROOT (http://root.cern.ch) is a system for data analysis and data mining that is used extensively by the high energy physics community. It has been adopted in other projects in physics, astronomy, biology, genetics, finance, pharmaceuticals, etc. Two papers for a quick introduction and advocacy are:
   "The Power of Object Oriented Frameworks", F. Rademakers
   ftp://root.cern.ch/root/frameworks.ps.gz
   ROOT - An Object Oriented Data Analysis Framework, F. Rademakers and R. Brun
   ftp://root.cern.ch/root/laussanne.ps.gz

 • POOMA (Parallel Object-Oriented Methods and Applications) is a framework for "high-performance scientific computation" for applications using uniform meshes and linear algebra based solvers.
   http://www.acl.lanl.gov/pooma/html/tut-07.html

 • Cactus is a name used by two frameworks projects, but the one most relevant here is the one that was originally designed for solving Einstein's equations. It is evolving to a general package for PDEs.
   http://cactus.aei-potsdam.mpg.de

• Overture targets CFD and combustion in complex moving geometry using structured grids or overlapping structured grids.
  http://www.llnl.gov/casc/Overture/

• AIPS++ is a framework for astronomical image processing.
  http://aips2.nrao.edu/docs/html/design.html
  It is built on a scripting language GLISH that was originally designed for the Superconducting Supercollider.
  http://aips2.nrao.edu/docs/glish/glish.html
  AIPS++ breaks several of the software engineering rules stated elsewhere in this CAN, primarily because it was designed so early before many of the rules could have been made.

• Ralph Johnson's frameworks page has a wealth of information:
  http://st-www.cs.uiuc.edu/users/johnson/frameworks.html

APPENDIX C
The Earth System Modeling Framework (ESMF)

Focus on interoperability along with performance of Earth Science modeling codes

This CAN addresses the need for model interoperation in global climate research to support NASA's flight missions and its role in the Global Change Research Program. This has been identified as a top priority in the Earth Science Strategic Enterprise Plan 1998-2002 (see Appendix F). For this reason, ESS will team interested Investigations and facilitate their joint specification of a mutually beneficial Earth System Modeling Framework (ESMF) with well defined interfaces, facilitate the joint construction of the framework, and assist the Investigations in developing high performance high-level plug-in applications compatible with the framework and enabling the interoperation of existing community models. The ESMF project is intended to replicate the successes of existing frameworks in other disciplines and thereby fortify standing efforts within the Earth Sciences community.
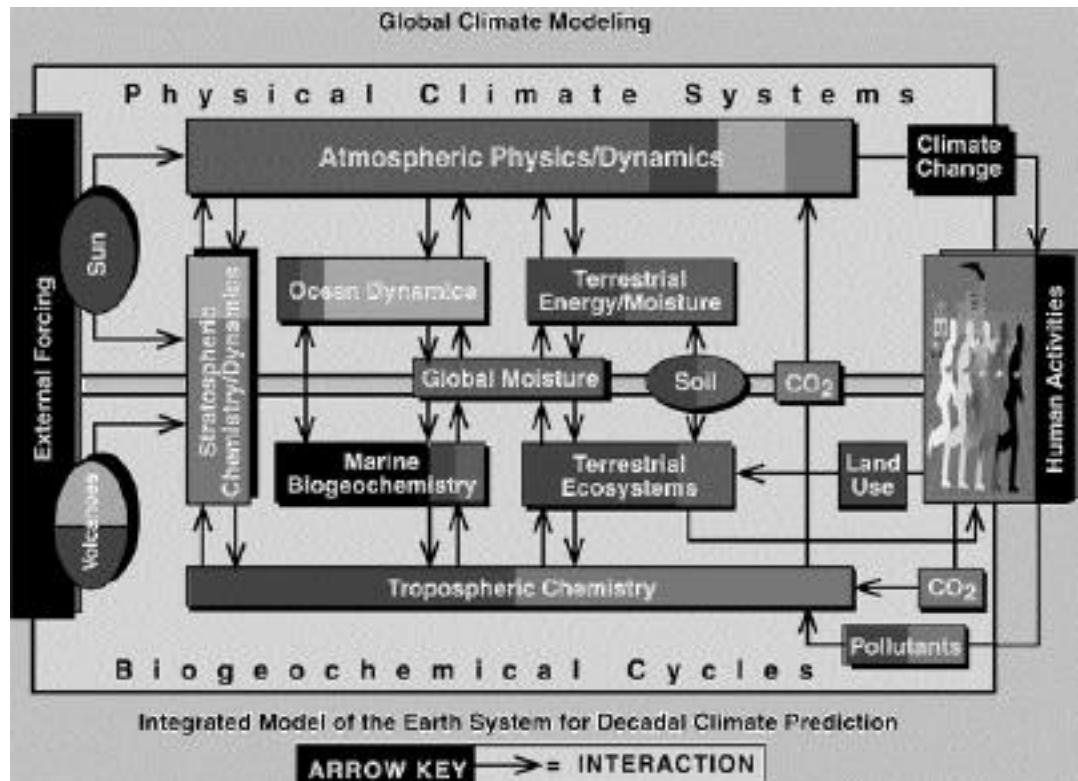
*Figure-5, The Earth system and its interactions.
From page 3 of the NASA Earth Science Strategic Enterprise Plan 1998-2002*

NASA's Earth Science Enterprise endeavors to understand the total Earth system and the effects of natural and human-induced changes on the global environment. This work takes place in the interdisciplinary field of Earth System Science, which has as its goal obtaining scientific understanding of the entire Earth system on a global scale by describing how its component parts and their interactions have evolved, how they function, and how they may be expected to

evolve on all time scales. The challenge to Earth System Science is to develop the capability to predict those changes that will occur in the next decade to century, both naturally and in response to human activity. NASA's unique capability for remote sensing of the Earth from space, coupled with *in situ* observation and modeling activities, provides the data needed on global, regional, and sometimes local scales to fuel that understanding and to begin to answer questions such as, *How can we utilize the knowledge of the Sun, Earth, and other planetary bodies to develop predictive environmental, climate, natural disaster, resource identification, and resource management models to help ensure sustainable development and improve the quality of life on Earth?*

Figure-5 shows the Earth system and its interactions, encompassing both natural and human activities. Projecting the future climate requires understanding and quantitatively predicting how the components and interactions will change as a result of natural and human activities. New scientific understanding will enable policymakers, commercial firms, and national, state, and local governments to make sound decisions. Practical applications will lead to synergistic partnerships among public and private sector entities.

 "Global modeling in the U.S. is at a critical crossroads. The degree of future progress will depend on the approach to development," reads the report of the August 1998 *NSF/NCEP Workshop on Global Weather and Climate Modeling*. The report goes on to say, "Over the years, many talented individuals in this country have produced numerous modeling innovations that are found in the wide spectrum of models that are used for weather prediction and climate modeling worldwide, both in operations and research. Yet, it is the diversity among the U.S. models that now is creating serious barriers to progress by limiting collaboration among the various modeling groups… Workshop participants unanimously agree that global atmospheric model development and application for climate and weather in the U.S. should be based on a common modeling infrastructure. In addition, there should be core models, which not only follow the infrastructure but advance it." [The full text of this report can be found at http://nsipp.gsfc.nasa.gov/infra/report.final.html]

ESS has set an objective in Round-3 of facilitating movement of a critical mass of the NASA Earth system modeling community to a common modeling infrastructure as called for above. This CAN will be responsive to proposals submitted in support of this objective and is preparing to actively facilitate the joint definition of an Earth System Modeling Framework (ESMF) by a significant portion of the U.S. climate modeling community and migration of their codes to this framework. To ensure this, at least three high quality proposals must be selected to participate in the ESMF project. The ESMF project will be a collaborative effort between the ESS Project, the Round-3 Investigator Teams proposing participation in it, and some interested non-funded members of the Earth Sciences community. The Headquarters Selection Official intends to identify membership in an Earth System Modeling Framework Science Team to oversee this activity.

ESS is a charged with enabling an array of Earth System modeling efforts. There is a goal of bringing disparate efforts together, not elevating one to a higher status and forcing others into line. When the ESMF is finished, it should enable the creation of the next generation earth system models and allow for a variety of plug-in components that interoperate with these models. By itself, it will not be the next generation model. To achieve these goals, ESS must look across earth system modeling efforts and provide technical information that is viewed as "objective" or "neutral" with respect to individual modeling efforts. It must also provide leadership in the framework design to insure a design and toolset that aids not hinders the achievement of milestones by participants. To this end, the project will:

- Maintain distinctions between the ESMF integrator and the PI Teams to insure that the integrator is not perceived as representing the interests of particular teams over others

- Appoint a Deputy Project Scientist to chair the ESMF effort who is not associated with any of the Investigator Teams

The scientific community has been slow to embrace object-oriented programming languages because standard Fortran has proven to provide higher performance. ESS expects the ESMF to be implemented at a high level; low level performance critical code will probably remain in Fortran or C. Approaches for mixing languages abound. At the very least, it will be necessary to write object-oriented "interface wrappers" around existing portions of software so that standard communication methods can be used. The framework will be constructed using accepted software engineering principles such that:

- Using the framework, *plug-compatibility* is demonstrated with foreign objects and applications codes.
- Shareable class libraries are clearly defined.
- Data are local to major components of the framework; there are no global variables.
- Data are communicated between framework components using the standardized interfaces; there are no multiple entry points within a module.
- Wherever possible, standards and COTS software are employed. For example, web aware clients could be implemented in Java; scripting languages could look like C++; and databases could follow CORBA standards.
- High performance will always be required by challenging problems and remains an overarching programmatic goal. The frameworks need to be designed such that model performance is not significantly degraded. A key feature to facilitate enhancement of model performance is designing in flexibility so that new and faster algorithms can be easily tried and adopted.

The Open Source model applies a strong natural selection to software by engaging an entire community in development and testing. The primary manifesto "The Cathedral and the Bazaar" by Eric S. Raymond [http://www.tuxedo.org/~esr/writings/cathedral-bazaar/] highlights several lessons learned that are often echoed by other object oriented software developers. Those most important to Round-3 efforts are likely to be: *beware of excessive top down design*, *plan to throw one away*, *good data structures and bad code will take you farther than the reverse*, *treat your users as co-developers*, and *it's not finished until you can't think of anything else to remove*. A giant monolith is not the goal that is promoted by insisting on strong software engineering in Round-3.

NASA will provide the services of a software engineering organization, termed the *ESMF Integrator*, during Round-3 to facilitate and support significant technical interaction among the selected Investigator Teams to carry out the ESMF effort. The ESMF Integrator's staff assigned to ESS will be members of the ESS Inhouse Team, providing software engineering expertise. They will serve as the integrator of the ESMF through the specification, design, and prototyping phases with significant technical contributions from the participating Investigator Teams at each step. The Investigator Teams will be responsible for implementing their codes in conformance with the resulting framework.

During the time interval between the release of the Round-3 CAN and the signing of the Cooperative Agreements, the ESMF Integrator is tasked to perform several key time critical preparatory activities to support ESS during the CAN negotiations in early Calendar Year 2000 and jumpstart the work of the ESMF Science Team once Cooperative Agreements are signed. These activities include:

1) Assessing framework requirements of existing numerical modeling applications that are candidates to interoperate in the ESMF;

2) Comparing and contrasting some existing relevant high performance frameworks for design principles and lessons learned;

3) Constructing the rationale and weaknesses for a strawman framework that could unite the candidates into a single high performance framework;

4) Developing definitions of candidate abstract modules for the strawman framework.

In order to give visibility to these preparatory activities, invite scrutiny by the benefiting community and support feedback on the direction and progress, deliverable items developed by the ESMF Integrator will be placed on the web at [url:...], and a method of receiving comments by email will be set up.

APPENDIX D
Testbeds

The ESS Investigator objectives listed in Section 4 are complemented by the following Testbed objectives, which link with the selected Teraflop/s Scalable Testbed vendor, the inhouse Commodity Based Testbed staff, and NASA inhouse computer and computational scientists:

(i)   Enable the Investigators to achieve their code improvement milestones, thereby assisting them to make significant progress in solving their Grand Challenges;

(ii) Explore the role of large clusters of inexpensive commodity PCs in supporting Grand Challenge Investigations and meeting large scale Agency computing requirements;

(iii) Reveal architectural features that enable/inhibit scalability to multi-teraflop/s performance for ESS applications; and

(iv) Participate in the integration of scalable parallel systems as robust components of the balanced production computing environments needed by the broader ESS community.

In support of these objectives, ESS plans to provide capability computing testbeds and applications support for Round-3 Investigations including:

 • A Teraflop/s Scalable Testbed able to sustain 125 gigaflop/s on benchmarks.

 • Access to a larger version of the Teraflop/s Scalable Testbed able to sustain 250 gigaflop/s on benchmarks. (access available 5% of wall clock time).

 • A Commodity Based Cluster running the Linux operating system; cluster size to be driven by Investigator needs.

D.1 Teraflop/s Scalable Testbed

A large parallel computing platform, able to sustain 125 gigaflop/s on benchmarks, herein referred to as the Teraflop/s Scalable Testbed (TST), will be sited at GSFC to support ESS Project activities. It is anticipated that one vendor will be selected through a full and open competition to provide the TST and to collaborate with the Round-3 Investigators in achieving their milestones. Progress on the TST acquisition can be monitored on the web (see Appendix F). The following list shows the groups that will receive access to the TST and the percentage of the total resource that they will share:

  1) ESS Grand Challenge Investigators selected through this CAN 55%

  2) Earth and space sciences researchers selected through a Guest
     Investigator program (described in Appendix E); 20%

  3) Experimental use by Investigators selected by the NASA HPCC
     Computational Aerosciences Project; 15%

  4) Support activities of the ESS inhouse team staff; 5%

  5) Experimental use by NASA fellowship awardees; and 3%

  6) Evaluation experiments organized by the ESS Evaluation Team. 2%

It is also anticipated that the same vendor will provide access to a larger Testbed, which may or may not be co-located with the TST. It will have at least twice the capability of the TST but will

only be used for milestone or capability demonstration runs, which are estimated to require 5% of wall clock time. Investigator access to the larger testbed will be by arrangement with the vendor.

The vendor will be required to provide strong applications support to assist Round-3 Investigations to achieve negotiated code improvement milestones G and H (see Sections 1-3 of Appendix A) when these milestones have been negotiated with quantified performance metrics. The vendor will be required to provide support to assure that at least 50% of these milestones are met. It is anticipated that the vendors will develop long term strategies with the Investigators to support code restructuring and optimizations geared toward Investigator milestone achievement.

Negotiations with Round-3 Investigators may complete before the TST vendor is selected. Provision is being made to retain ESS access to the 512 processor Cray T3E, currently at GSFC, for initial Round-3 Investigator code baselining and milestone achievement.

D.2 Commodity Based Testbed

The ability to construct powerful cluster computers entirely from commodity components offers a new dynamic in the evolution of large systems, allowing leading edge mass market consumer products to be deployed on the computer room floor to support the scientific community as soon as they are released for public sale. Since 1995, ESS has integrated four generations of Linux based commodity clusters and plans to continue this approach throughout the time period of Round-3.

Various shortcomings in the Linux system software environment are obstacles in their movement to the production computing floor. ESS plans to release a separate solicitation to address these shortcomings after all Cooperative Agreements are signed and the Round-3 Science Team can help ESS to prioritize their needs. Investigators are encouraged but not required to make significant use of Linux clusters including: 1) construction of a Linux cluster at their home sites for code development, and 2) achievement of performance milestones on a large ESS provided Linux cluster (see Sections 4 and 5 of Appendix A).

D.3 Testbed Availability, Guidelines and Network Access

The TST is intended to be available 24 hours a day, 7 days a week except for scheduled preventive maintenance and system upgrades. User support will be available Monday through Friday, 9AM to 5PM Eastern Time, and additionally on an arranged basis; operator support will also be available. The user support function, to be provided by the Testbed vendor, will provide training, consultation, and assistance with problems and help with planning and review of algorithm implementation to assure effective Testbed utilization. On-line and near-line storage space will be made available for each Investigator. The uniqueness of individual systems and limited experience with hardware and software failure can cause uncertainties in projecting overall reliability.

ESS Testbed computers will be accessible through vBNS, NASA Integrated Services Network (NISN), and the NASA Research and Education Network (NREN), as well as through other NGI networks such as the other "JETnets" (e.g., Abilene, vBNS, ESnet, DREN) or the DARPA SUPERNET (e.g., NTON, MONET, OnRamp). High speed network backbone paths running at a minimum rate of 622 megabits per second (Mbps) will connect the various NASA HPCC testbed sites, with that bandwidth upgraded to __ Mbps by _date_.

D.4 Other Computing Facilities

Investigator Teams are expected to use the TST to achieve their milestones. In addition, ESS will provide access to other high performance computing testbed research facilities including a Cray T3E at GSFC, an SGI Origin 2000 at ARC, and an HP Exemplar at the California Institute of Technology (Caltech) to the extent resources permit. Each of these Testbed facilities is supported locally. Investigator Teams are encouraged to use other scalable parallel systems available to them where such use will yield enhanced code portability and understanding of performance from comparative analyses.

APPENDIX E
Summary of ESS Round-3 Activities

The ESS Project is a component of the NASA High Performance Computing and Communications (HPCC) Program, which is a critical element of the Federal Program in Computing, Information and Communication. Sources of information on both the Federal and NASA programs are listed in Appendix F.

The goals of the NASA HPCC Program are to accelerate the development, application, and transfer of high-performance computing and computer communications technologies to meet the engineering and science needs of the U.S. aerospace, Earth and space sciences, spaceborne research, and education communities and to accelerate the distribution of these technologies to the American Public. This work is carried out to enable NASA to narrow the computing gap that now exists between current computing and data management capabilities and the requirements of NASA scientists, engineers, and flight missions, thereby addressing strategically important computational problems that are beyond current capabilities. ESS is one of five projects in the NASA HPCC Program, the others being Computational Aerosciences (CAS), Remote Exploration and Experimentation (REE), the NASA Research and Education Network (NREN), and Learning Technologies (LT).

The ESS Round-3 effort is a comprehensive set of complementary activities coordinated by the ESS Project Office to bring together capabilities and expertise in support of the ESS goals. The left column below names the activity, and the right column states where it is described in this CAN:

- Round-3 Grand Challenge Investigations	Section 6
- Teraflop/s Scalable Testbed with support staff for performance optimization and operations	Appendix D
- Commodity Based Testbed, with support staff for development, performance optimization, and operations	Appendix D
- Earth System Modeling Framework Integrator	Appendix C
- Solicitations for High Performance Plug-ins	Appendix E.1
- Guest Investigator Program	Appendix E.2
- Guest Investigator Facility	Appendix E.3
- Performance Evaluation staff	Appendix E.4
- GSFC and JPL Center based staff developing applications middleware and plug-in software	…
- NASA based research in visualization, mass storage, and networking	…
- Visualization task order services	…
- Basic research awards program in system software	…
- Fellows program	…

E.1 Solicitation for High Performance Plug-ins

The ESMF Science Team and the various other framework communities that ESS Round-3 Investigations will represent are likely to find that their science would rapidly benefit from the availability of specific high performance software objects compatible with their framework. ESS work has tended towards the "grandest" challenges, but excellent, cutting-edge applications may be done in more "component" areas. Software components could be provided by groups

within the various framework science communities and many could come from other groups, such as numericists, expert in their field, who may not typically be involved in support of the branch of science represented by the benefiting framework community. Once the ESMF definition is agreed to, ESS plans to assess specific needs of the ESMF community and the other Round-3 related framework communities and to issue a solicitation separate from the Round-3 CAN for 'plug-in' software objects. Awards will be for specific software deliverables, and each awardee will need to have a provider/customer relationship with one or more members of a Round-3 framework community. Awards will typically be valued at $50K - $100K per year and extend over two years. Between 10 and 20 such awards are envisioned to be active at any time. ESS envisions follow-on 'plug-in' solicitations if significant benefit to NASA science can be shown, and has reserved approximately $7M total in FY 2001 through FY 2004 to fund 'plug-in' awards. The high performance plug-ins solicitation is not part of this CAN and will be announced at [http://esdcd.gsfc.nasa.gov/ESS/].

E.2 Guest Investigator Program

Beginning in FY01, NASA plans to conduct a biannual proposal solicitation process to give scientists from the broader Earth and space sciences community who receive NASA funding but are not funded under this CAN access to the Teraflop/s Scalable Testbed to assist them in preparing to use scalable parallel systems as they become available in production computing facilities. Twenty percent of the Teraflop/s Scalable Testbed will be made available for use by Guest Investigators. A limited amount of training and support will be provided for these users. The instructions and schedule for Guest Investigator proposal submissions will be posted at [http://esdcd.gsfc.nasa.gov/ESS/].

E.3 Guest Investigator Facility

The ESS Project operates a Guest Investigator facility at GSFC to house members of Investigator Teams when they visit for periods of time to work closely with the Testbed vendor and NASA inhouse computer and computational scientists.

E.4 Performance Evaluation

ESS considers evaluation to be an essential part of Round-3 and will provide a technical evaluation staff of computer scientists specializing in computer system evaluation as part of the ESS Inhouse Team. They will assist the Investigator Teams in characterizing their applications codes and in carrying out performance and scaling measurements on the Testbeds. Performance evaluation will focus on the large scale Grand Challenge codes and their interactions with the parallel testbed systems. Evaluation will include the static and dynamic characteristics of the codes that affect performance and interoperability as well as characteristics of the testbeds that affect performance and usability. An objective of the evaluation work will be identification and understanding of the critical success factors for the selected Grand Challenge Investigations. Expected output of the evaluation work is direct feedback to the Teams as well as analytic articles in professional and trade journals.

The goal of the evaluation effort is to understand the characteristics and interactions among the characteristics of the computational platform, the application code and the physical model being studied. This understanding will help ESS predict and deliver the computational resources required to meet the goals of NASA research scientists and flight missions. The inhouse evaluation team proposes a layered approach to this problem. The approach will involve the collaboration of vendors, inhouse team, and PIs, focusing on different points where the layers are integrated into the framework being used.

Each team will identify a point of contact for the inhouse evaluation team. This person will be responsible for explaining the software engineering scheme employed in the application and will assist in correlating the key scientific contributions of the application with modules within the framework being used. At the highest level, the PI Teams are responsible for identifying scientific progress and, through the contact person, will assist the inhouse team in identifying code improvements that are responsible for that progress. At the lowest level, the inhouse team will work with the PI Team to obtain scaling curves for the entire application and for each of the components within the framework using conventional performance monitoring tools as provided by the testbed vendors. In between, the inhouse team will work with the PI Team to correlate the computational load specified by the application code with the performance of the testbed while executing the application. The primary tool will be software instrumentation that will measure individual modules and perhaps more importantly measure the interaction among the modules in the framework. The inhouse team will instrument key modules and the interfaces between modules and will work with the point of contact to track the evolving application code. Using software instrumentation to study the memory access and communication patterns, both within modules and between modules, may provide the bridge between performance improvement as measured by the scientific milestones and more traditional measures of computer performance.

E.5 Summary – Round-2 of the ESS Project

In Round-2 (FY96-9), nine Grand Challenge Investigator Teams and a Testbed vendor were selected to work in close collaboration to achieve negotiated end-to-end performance goals on specified Investigator codes.

Both the Round-2 Investigators and the Testbed vendor were acquired through a single Cooperative Agreement Notice (CAN-21425/041) structured to use milestone payments to incentivize strong collaboration between the Testbed vendor and the Investigators to meet aggressive ESS performance milestones of 10, 50, and 100 gigaflop/s sustained (or 200 fold improvement over baseline) on Investigator codes. The CAN was released in May 1995, proposals were received in August 1995, and a full peer review was carried out for the Investigator proposals. All 10 Cooperative Agreements between GSFC and Investigator institutions, worth $12.6M in total, had been signed by the fall of 1996. All Cooperative Agreements are worded identically and a sample can be found at [http://esdcd.gsfc.nasa.gov/ESS/can.invagree.html]. The sample contains all sections except the last section "18. Milestone Schedule and Payments" which contains the milestones and which is unique to each agreement. The Cooperative Agreement between GSFC and SGI/Cray was worth $13.2M. All Cooperative Agreements have lifetimes of approximately three years. Descriptions of the nine Round-2 ESS Grand Challenge Investigations can be found at [http://esdcd.gsfc.nasa.gov/ESS/grand.st2.html].

The negotiated milestones focused Round-2 teams to achieve a 200 fold improvement in computational capability over the project's 1992 baseline. All codes that achieved performance milestones were required to be documented and released to the science community on the web through the National HPCC Software Exchange (NHSE) [http://www.nhse.org]. All payments under the Round-2 Cooperative Agreements were tied to achievement of milestones. A table of all Investigator and Testbed vendor milestones is found at [http://esdcd.gsfc.nasa.gov/ESS/can.milestones.html]; these are Level-3 milestones in the NASA HPCC Program. There are 117 negotiated milestones worth a total of $25,803,000. The Cooperative Agreement with Cray Research Inc. resulted in placement of a large scalable parallel Testbed (512 processor Cray T3E) at GSFC, primarily to support the research needs of the Round-2 Investigators but also to assist in transitioning the broader NASA science

community to parallel computing and to support research of the HPCC Computational Aerosciences (CAS) Project. An additional 512 more processors were added to this Testbed in 1998 by the Earth Science Enterprise to support the production computing requirements of the NASA Seasonal to Interannual Prediction Program (NSIPP).

As of November 1999, all nine ESS Round-2 Grand Challenge Teams had achieved 10 gigaflop/s sustained performance on their code(s) as negotiated and submitted these 10 gigaflop/s codes to the National HPCC Software Exchange (NHSE), eight had achieved 50 gigaflop/s sustained, and seven had submitted their 50 gigaflop/s codes to the NHSE. Seven had achieved 100 gigaflop/s sustained performance or a factor of 200x over baseline, and three had submitted their 100 gigaflop/s codes to the NHSE.

APPENDIX F
World Wide Web References to Project Information

• Address questions regarding this CAN to:

> Ms. Ann T. Kearney, ___
> Code 219
> NASA Goddard Space Flight Center
> Greenbelt, MD 20771
> E-mail: akearney@pop200.gsfc.nasa.gov

• Letters of intent are to be submitted via a web form found at:

> http://esdcd.gsfc.nasa.gov/ESS/CAN2000/CAN.html

• The NASA Grant and Cooperative Agreement Handbook can be accessed at:

> http://genesis.gsfc.nasa.gov/grants/grants.htm#GrantsForms

• Learn the history of the ESS Project and obtain electronic copies of this announcement at:

> http://esdcd.gsfc.nasa.gov/ESS/

• Read the ESS Round-2 Investigator Cooperative Agreement:

> http://esdcd.gsfc.nasa.gov/ESS/can.invagree.html

• Read the draft ESS Round-3 Investigator Cooperative Agreement:

> http://esdcd.gsfc.nasa.gov/ESS/CAN2000/CAN.html

• Access the ESS Software Repository at:

> http://esdcd.gsfc.nasa.gov/rib/repositories/ESS/catalog/index.html

• Monitor acquisition of the Teraflop/s Scalable Testbed:

> ....

  • Obtain copies of the benchmark problems for the Teraflop/s Scalable Testbed acquisition via anonymous ftp at:

> ftp://esdcd.gsfc.nasa.gov/pub/HPCC/ESS/testcases

• Monitor preparatory activities for Earth System Modeling Framework:

> ....

• Monitor the solicitation for high performance Plug-in applications:

> ....

• Monitor the schedule for submission of Guest Investigator applications:

   ....

• Obtain information about the NASA HPCC Program, including annual reports, at:
   http://hpcc.arc.nasa.gov/

• Obtain the NASA Strategic Plan at:
   http://www.hq.nasa.gov/office/nsp/

• Obtain the Earth Science Strategic Enterprise Plan 1998-2202 at:
   http://www.earth.nasa.gov/visions/stratplan/index.html

• Obtain the Space Science Enterprise Strategic Plan at:
   http://spacescience.nasa.gov/strategy/1997/

• Obtain the Human Exploration and Development of Space (HEDS) Enterprise
   Strategic Plan at:
   http://www.hq.nasa.gov/office/olmsa/lifesci/index.htm

• Obtain information about the Federal program in Computing, Information and
   Communications (CIC), including the documents listed below, from the:

   National Coordination Office for Computing,
     Information, and Communications   http://www.ccic.gov/
   Suite 690   Phone: 703-306-4722
   4201 Wilson Boulevard   FAX: 703-306-4727
   Arlington, VA 22230   E-mail: nco@ccic.gov

   - President's Information Technology Advisory Committee Report to the President
     "Information Technology Research: Investing in Our Future"
     February 1999
     http://www.ccic.gov/ac/report/

   - FY 2000 Blue Book, April 1999

     "High Performance Computing and Communications: Information Technology
       Frontiers for a New Millenium"

     http://www.ccic.gov/pubs/blue00/contents.html

   - FY 2000 Implementation Plan, June 1999

     "Information Technology for the Twenty-First Century: A Bold Investment
       in America's Future"

     http://www.ccic.gov/pubs/it2-ip/

• Report from the "NSF Workshop On a Software Research Program For the 21st Century"
   October 1998
   http://www.cs.umd.edu/projects/SoftEng/tame/nsfw98

APPENDIX G
Guidelines for Grand Challenge Investigation Proposals

G.1 Peer Review Process

A full peer review will be carried out under the supervision of the Technical Review Committee, which will ensure impartiality. This committee is chaired by the HPCC Program Manager in the Technology Division in the Earth Science Enterprise at NASA Headquarters. The peer review will be based on Evaluation Criteria areas I through III stated in Section G.7. Scientists who are knowledgeable and experienced in the relevant areas of science, as well as technologists who are familiar with software engineering, parallel computational techniques, supercomputer architectures and systems, visualization and networking, will be chosen to review the proposals. Proposals will be sent out to two sets of mail reviewers and be rated on their scientific and technology qualities. Based on the mail reviews, the Technical Review Committee will select the top 20-30 rated proposals for the panel review. No further consideration will be given to the remaining proposals. Peer review panels in Earth Science, Space Science, and Technology will be convened. Investigator Team proposals will be assigned to either the Earth Science or Space Science panel based on proposed science thrust. All proposals will be reviewed by the Technology Panel. The Earth Science and Space Science Panels will score proposals in the two Evaluation Criteria areas I and III. The Technology Panel will score proposals in the two Evaluation Criteria areas II and III. The scores from the scientific and technology panels will be merged by the Technical Review Committee, producing complete ratings for all proposals, and allowing all proposals to be ranked. Ranked proposals will then be forwarded to the Headquarters Selection Committee, which will ensure breadth, diversity, and relevance to NASA in the final selections (Evaluation Criteria area IV). The Selection Committee is chaired by the Head of the Science Division in the Earth Science Enterprise at NASA Headquarters, and populated by designated program managers from among the Earth Science Enterprise, Space Science Enterprise, Office of Life and Microgravity Sciences and Applications, and the Office of Aeronautics. The Selection Committee will then make its recommendations to the Selecting Official, who will select Teams for negotiations. ESS will carry out the negotiations and GSFC will sign Cooperative Agreements with those Teams that successfully complete the negotiation process.

G.2 Letter of Intent to Submit a Proposal

To determine the areas of expertise required of peer reviewers in advance, and to increase the efficiency of proposal management, it is required that all Grand Challenge Investigator proposers electronically submit a Letter of Intent by <__date__>. To do so, use the web based form at:

<div align="center">esdcd.gsfc.nasa.gov/ESS/CAN2000/CAN.html</div>

Any questions or problems with the form should be addressed to esscan@cesdis.gsfc.

Letters of Intent will include the following information:

    Name, address, and telephone number of the Principal Investigator;

    Name, address, and telephone number of any Co-Investigators;

    Tentative title of the investigation to be proposed;

    Brief abstract of the investigation to be proposed;

Checklist of science disciplines and computational science challenges addressed in the proposal (checklist will be provided electronically by NASA in the Letter of Intent format).

List of potential reviewers for the proposal including name, affiliation, phone number and email.

List of reviewers, including name and affiliation, from other than your organization who have a conflict of interest.

G.3 Data Rights [this part needs help from Patent Counsel]

In order to rapidly transfer the parallel algorithm and tool technology developed by Investigator Teams to the broader community, NASA will require such data to be delivered to the ESS Software Repository (see Appendix F) with unlimited rights in connection with the appropriate Rights in Data provision included in the resulting cooperative agreements. However, if the software is planned to be commercialized, then the Investigator Team(s) developing such a product may be exempt from the above submission requirement, provided that cost-sharing is proposed. If commercialization is planned, then Investigators must include a detailed cost sharing section in their proposal and specifically request to be exempted from the data delivery requirement.

G.4 Proposal Format, Content, and Page Limit

Proposals submitted by prospective Investigators in response to this CAN should be in the following order:

	Page Length
i. Research Proposal Cover Page (see Section G.8)	1 page
ii. Research Proposal Summary Forms (see Section G.8)	2 pages
iii. Research Domain Profile Form (see Section G.8)	1 pages
iv. Software Engineering Summary Form (see Section G.8)	1 page
v. Software Engineering Plan	2-3 pages
vi. Scientific/Technical Section To facilitate peer review, please organize this section to present your scientific case first followed by your technical case and please identify each section.	15 pages (including Table of Contents, all figures and references)
vii. Biographical Sketches	maximum 1 page each PI and Co-I
viii. Milestones/Deliverables/Cost (see Appendix A) (a traditional budget page should not be submitted)	3 pages
ix. Endorsement letters from other institutions	1 page per institution

Proposals are expected to be written concisely in English to minimize the burden on the reviewers and to facilitate the overall evaluation process. The proposal should be prepared on 8.5" x 11" paper, single- or double-spaced (point size 12 or larger, with 1-inch margins), with pages in the order listed above. Smaller font size may be used for figures and captions only. Appendices are not permitted. Double-sided printing is encouraged. Note that reviewers will only read proposals submitted in the correct format, to the maximum page limits listed above.

Color images are allowed; however, a color image must be included in each proposal copy. NASA will not be responsible for reproducing color materials. Do not include videotapes, CD-ROMs, or other electronic media; they will not be viewed.

When completing the prefatory forms, please note that, for proposals in response to this CAN, NASA recognizes only <u>one</u> Principal Investigator (PI) for each proposal. Other Investigators are designated Co-Investigators (Co-Is), even if their proposal and science responsibilities are comparable to that of the PI.

The proposer's sponsoring institution must endorse each proposal. Only properly endorsed proposals are acceptable. The Cover Page contains space for this endorsement by an institutional representative authorized to legally bind the institution to perform the proposed effort. If substantial collaborations with other institutions are involved, then letters of endorsement should be submitted by the responsible officials from those institutions. Each endorsement letter should indicate agreement with the nature of the collaboration detailed in the proposal, which should be identified by title and date of submission. All endorsement letters should refer to the Earth and Space Sciences Project of the High Performance Computing and Communications Program of NASA's Earth and Space Science Enterprises.

To facilitate the recycling of shredded proposals after review, proposals should be submitted on plain, white paper only (except for color images). This precludes the use of cardboard stock, plastic covers, colored paper, and binders such as three-ring, GBC, spiral, plastic strips, etc.

G.5 Proposal Instructions

Most proposal items listed in Section G.4 are self-explanatory. Items vi and viii are described below in more detail.

The **scientific section** (item vi) must include the following:

- Identify the Principal Investigator and Co-Investigators. The teaming arrangement proposed for an Investigator Team should be complete and balanced, containing all necessary backgrounds and skills in the team to carry out the project including the physical and computational/computer scientists and the software engineers.

- List the objectives of the proposed investigation. Proposals are preferred which will make extensive use of NASA mission data. The handling of large data sets will be a key technology component of Round-3. State explicitly the importance and relevance of scalable parallel computing technology to enable the proposed science and justify value of proposed work in terms of new science results or mission support expected to result.

- Explain the scientific rationale. Identify a broader scientific community that will be served by the ESS technology program, provide a specific plan for delivering new capabilities to this community.

The **technical section** (item vi) must include the following:

- Identify the technical background and skills on your team to enable the implementation of software frameworks for your particular application.
- Present your software engineering plan including the process you will use to develop requirements, develop the software, conduct the testing, and deliver the final product.

- Describe the framework you anticipate implementing. If you are using an existing framework explain the extensions you anticipate making to meet your requirements. If you are designing a new framework explain the method to determine requirements and the method for designing and testing the framework. In both cases explain how this framework will enable interoperability and support the incorporation of new capabilities by your community. Explain how you will gain community buy-in for your framework and how you will deliver your product to the community and evaluate its acceptance and impact.

- Identify the model(s), analysis, or data processing application(s) that will be developed to meet the code improvement milestone(s). The ESS Project understands and expects that in order to achieve such large improvements, major recoding of the application programs may be required. Describe the approach to be taken and identify efforts required to redesign/restructure the codes to take full advantage of high performance parallel execution. Provide quantified metrics and milestone achievement criteria. The handling of large data sets will be one of the key technology components of Round-3. Describe specific work to be undertaken in this area.

- Due to the aggressive performance demands of the ESS Project, this CAN is intended for scientists currently using parallel systems. Show prior parallel computing experience in the scientific domain being proposed. At a minimum, submit evidence that the Investigator Team has successfully developed parallel applications in the proposed scientific domain that run on at least 128 processors concurrently with at least a 50% efficiency of scaling for a fixed problem size; include a plot of the speedup curve. List the platforms on which these application programs have been run, and corresponding application and code performance measurements.

- Present a management plan.

The **milestones/deliverables/cost** section (item viii) must include the following:

- Include a list of proposed milestones in a format similar to that shown in Sections 3 and 5 of Appendix A. Proposed milestones should include the 12 Required Investigator Milestones as described in Sections 1-3 of Appendix A and up to two optional milestones as described in Sections 4-5 of Appendix A]. Meaningful milestones spread throughout the three year award period must be proposed. Milestones will serve as a plan for code interoperation, code improvement, and administrative reporting. Milestones and payments will be finalized during negotiations prior to selection for award. Payments to Investigators will only be made upon the achievement and validation of a milestone. Milestones will not be paid out of order. It is the investigator's responsibility to structure the value of each milestone so that funds sufficient for the achievement of the subsequent milestone are paid out and available for Investigator use.

- List additional contributions to this research activity (i.e., institutional support for hardware procurements, partial funding of postdoctoral positions, etc.). Non-NASA resources should be verified by a letter of commitment signed by an authorized representative of the organization(s). Non-NASA funding sources should indicate the resources contributed and any conditions concerning the use of resources.

- Describe type and level of resource sharing in the proposed research, if that research will produce commercializable software. (This is not required of proposers who agree to submit resulting algorithms and tools to ESS Software Repository with unlimited rights in connection with the appropriate Rights in Data provision included in the resulting cooperative agreements.)

G.6 Proposal Quantity and Mailing Address

Twenty copies of each Investigator proposal should be sent to the following address:

U.S. Mail

<name tbd>
CAN-<__insert CAN number__>
<address tbd>

Commercial delivery service

<name tbd>
CAN-<__insert CAN number__>
<address tbd>

Proposals should be mailed so as to arrive at the above address by 4:30 pm (Eastern Daylight Time) on <__date__>, <year>. Offerors must either deliver their proposal by U.S. Postal Service Mail or hand deliver (includes the use of a commercial delivery service). Regardless of the delivery method chosen, the proposal must be closed and sealed as if for mailing. Late proposals will not be reviewed. To receive an acknowledgement of receipt of proposal, please attach a self-addressed, postage-paid postcard to the top proposal copy and it will be mailed back to you.

If the bid is to be delivered by a commercial delivery service such as United Parcel Service, Federal Express, DHL, Purolator, etc., place the following on the outside of the carrier's envelope or package cover:

CAN <__insert CAN number__>

Commercial Delivery Personnel:

This proposal must be hand carried directly to <insert Building #, Room #> and received by <__date__>, 1999. The room is open from 8:00 am to 4:30 pm, Monday through Friday, except Government Holidays.

G.7 Evaluation Criteria

Below are the review criteria to be considered in force for Investigator Team proposals. There are four principal elements to be considered: scientific quality of proposal and team, technical quality of proposal and team, cost, and other factors. The first two elements are equally weighted and significantly more important than the third, which is in turn significantly more important than the last. All elements will be evaluated subjectively.

I. Scientific quality of proposal and team

Evaluation of the proposal's scientific quality includes consideration of the following factors. No order of importance is implied:

   a. Scientific merit and breadth of proposed Grand Challenge application and its relevance to NASA science mission objectives;

   b. Incorporation of NASA data to understand Earth or space science phenomena;

   c. Scientific and computational expertise of the team proposed, including experience with large computational problems; past support of a broader user community in their field; and

    d. Strength of proposal to build community capabilities through software frameworks or other proposed techniques; value of proposed software deliverables to the science community.

II. Technical quality of proposal and team

Evaluation of the proposal's technical quality includes consideration of the following factors. No order of importance is implied:

    a. Feasibility of accomplishing code improvement goals with proposed resources, based on scaling projections derived from applications executed on current parallel computing systems;

    b. Strength of software engineering plan; clarity of process to document software requirements, enable interoperability, and deliver new capabilities to a broader community;

    c. Software engineering expertise of the team proposed to advance community software efforts, experience with user communities, expertise in creating interoperable code; and

    d. Feasibility of the approach to enable code interoperability and deliver new capabilities to a broader community.

III. Cost

Evaluation of the proposal's cost includes consideration of the following factors, listed in descending order of importance:

    a. The reasonableness and realism of the cost of the proposed effort and the relationship of the proposed cost to available funds; and

    b. Level of proposed cost-sharing (applies only to proposals which include development of commercializable software products for which data rights are retained by the Proposer).

IV. Other factors

The success of the ESS Project depends partially upon the richness and diversity of applications, algorithms, and data handling methods examined and the potential for synergy—the extent of technology transfer and training of eventual users, as well as the potential for benefits and insights from participation in a multidisciplinary environment. Other factors such as duplication of research, possibility for product commercializability, minority participation, and program balance will be considered and incorporated in an overall assessment.

G.8 Required Proposal Forms

    - Research Proposal Cover Page
    - Research Proposal Summary Form (Parts I, II, and III)
    - Research Domain Profile Form
    - Software Engineering Summary Form

These five forms are on the following five pages.

These blanks for NASA use only: [try reformatting with boxes]
Log No.: _____
Date Received: _____
CAN No: CAN-<__insert CAN number__>

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance of Grand Challenge Applications in the Earth and Space Sciences

RESEARCH PROPOSAL COVER PAGE

_____

_____
Proposal Title

_____
Principal Investigator's Signature and Date

_____
Typed Name and Title of Principal Investigator

_____
Principal Investigator's Telephone Number with Area Code

_____
Principal Investigator's E-mail address

_____
Name of Institution

_____
Authorizing Institutional Official's Signature and Date

_____
Authorizing Institutional Official's Typed Name and Title

_____
Authorizing Institutional Official's Telephone Number with Area Code

_____

_____

_____

_____

_____

_____
Institutional Address, including Postal Code and Country

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance
of Grand Challenge Applications
in the Earth and Space Sciences

RESEARCH PROPOSAL SUMMARY FORM -- Part I

- Proposal Title:

- Principal Investigator's Name, Institution, and E-mail address:

- References to related work:

- Abstract: (200 to 300 words):

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance
of Grand Challenge Applications
in the Earth and Space Sciences

RESEARCH PROPOSAL SUMMARY FORM -- Part II

- Co-Investigator's Full Name(s), Institution(s), and E-mail address(es):

- Budget Summary by Federal Government Fiscal Year: (total value of milestones expected to be achieved in these timeframes)

NASA FY:	2000:	2001:	2002:	2003:
	6/00 - 8/00	9/00 - 8/01	9/01 - 8/02	9/02 - 8/03
Total Request:				

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance
of Grand Challenge Applications
in the Earth and Space Sciences

RESEARCH PROPOSAL SUMMARY FORM -- Part III

• In order to evaluate the reasonableness of the costs associated with proposal milestones, please fill in the following table.

Instructions:
Identification: List in this column all individuals identified by name in the proposal. Also list other categories of workforce to be used in this effort such as post docs, grad students, professional staff, administrative staff, technicians, etc.
Job title: ___
FTE: The approximate portion of time to be spent on the proposed work over the lifetime of the award.
Fully Burdened Total Cost: total cost for all years of this effort.

Example:

Identification	Job Title	FTE	Fully Burdened Total Cost
John Doe	Professor	.33	$555k
Sam Smith			
Jane Air			
Post Doc			
Staff 1			
Staff 2			
....			
Others (Students, etc.)			

Proposal Response:

Identification	Job Title	FTE	Fully Burdened Total Cost
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance
of Grand Challenge Applications
in the Earth and Space Sciences

RESEARCH DOMAIN PROFILE FORM

Please submit a copy of this profile with your proposal. Mark, with an X, all items that apply and f
in any "Others" items that apply as well. These domains are not assumed to be comprehensive, and
omissions are not implied to be less desirable.

I. Domain Sciences
_____ Solid Earth Science
_____ Ocean Science
_____ Atmospheric Sciences
_____ Aeronomy
_____ Magnetospheric Physics
_____ Heliospheric Physics
_____ Astrophysics
_____ Life Sciences
_____ Microgravity Sciences
_____ Solar System Exploration
_____ Other _____

II. Fundamental Disciplines
_____ Particle Physics
_____ Electromagnetic and Radiation Physics
_____ Classical Mechanics
_____ Quantum Mechanics
_____ General Relativity
_____ Solid State Physics
_____ Statistical Physics
_____ Physics of Solids
_____ Fluid Dynamics
_____ Gas Dynamics
_____ Plasma Physics
_____ Chemistry
_____ Biology
_____ Other _____

III. Computational Engineering
_____ data assimilation
_____ scientific visualization
_____ image processing
_____ data browsing/navigation
_____ mass storage/intelligent databases
_____ grid generation
_____ parallel programming/partitioning
_____ particle methods
_____ Other _____

IV. Computational Techniques

_____ methods for ordinary diff. equations
_____ explicit
_____ implicit
_____ adaptive
_____ methods for hyperbolic PDEs
_____ high order Godunov methods
_____ shock-capturing methods
_____ semi-implicit methods
_____ semi-Lagrangian methods
_____ specialized advection algorithms
_____ specialized Riemann solvers
_____ methods for elliptic PDEs
_____ direct methods
_____ iterative methods
_____ multigrid methods
_____ Krylov subspace methods
_____ preconditioners
_____ methods for parabolic PDEs
_____ finite difference methods
_____ classical
_____ adaptive stencil
_____ compact
_____ finite element methods
_____ p- and h-refinement techniques
_____ spectral and spectral element methods
_____ wavelet methods
_____ particle methods
_____ PIC codes
_____ hybrid codes
_____ tree codes
_____ PPPM codes
_____ fast multipole expansion methods
_____ fast transform methods
_____ unstructured grid methods
_____ solution-adaptive grids and methods
_____ specialized filters
_____ Other _____

HPCC/ESS Cooperative Agreement Notice (CAN)

Increasing Interoperability and Performance
of Grand Challenge Applications
in the Earth and Space Sciences

FRAMEWORK FOR INTEROPERABILITY SUMMARY FORM

Please submit a copy of this profile with your proposal. Mark, with an X, all items that apply
and provide descriptive text as called for. Please limit your response to this single page.

_____   Proposing Team requests to be part of the Earth System Modeling Framework (ESMF)
Science Team.

_____   Proposing Team is involved with an existing community framework to be used/enhanced
during Round-3. Please identify framework and its participating community:

_____   Proposing Team will be involved in bringing about a community framework during
Round-3. Please identify benefitting community and describe planned process for
achieving agreement by community participants.

APPENDIX H
Preproposal Conference

NASA Goddard Space Flight Center will host a preproposal conference relevant to this CAN on __day, <month> <day>, 2000, from 9:00 AM until 2:00 PM. The purpose of this conference is to provide a forum for potential Proposers' questions. The conference will be held at Goddard in the Building 8 Auditorium [maybe Building 28]. Organizations and individuals planning to attend this conference are requested to preregister with Georgia Flanagan, no later than __day, <month> <day>, at 301-286-2080 or georgia@cesdis.usra.edu.

Foreign nationals planning to attend the conference who have a green card must present it at the Goddard main gate in order to be admitted. Those who do not hold a green card must apply two weeks in advance to be cleared by the Goddard International Coordinator. Call Georgia Flanagan at 301-286-2080 immediately to begin the process of securing admittance to Goddard.

Directions to Goddard [this may all be replaced by a URL]

NASA/Goddard Space Flight Center is located approximately 15 miles Northeast of the center of Washington, DC, and one mile East of Greenbelt, Maryland, three miles off Interstate Highway 95.

Two maps are provided on the following page to assist travelers in reaching Goddard. One shows Goddard's location with respect to major highways to the Northeast of Washington, DC, and the other shows the local roads connecting Goddard to Interstate 95. From Interstate 95, take Exit 23 (Kenilworth Avenue - Maryland Route 201) South. At the first interchange, go left (East) on Greenbelt Road (Maryland Route 193). Stay on Greenbelt Road for 3 miles. The main gate for Goddard will be on the left at a traffic light.

Visitors should park in the visitors' parking lot located outside the main gate and to the right (East) of the road leading into the campus. From the parking lot, walk into the guard house to sign in. Tell the guard at the desk that you are attending the "Preproposal Conference for HPCC" in the Building 8 Auditorium. You will receive a temporary badge, car pass and map of the Goddard campus. Drive to the Building 8 parking lot, located across Goddard Road from Building 8. The auditorium is on the second floor.

Map to NASA/Goddard Space Flight Center available via FAX upon request

[insert map page next]

APPENDIX I
Definition of Terms [may delete]

- *capability computing* _____ [definition]

- *capacity computing* _____ [definition]

- *contract* _____ [definition]

- *Cooperative Agreement* _ [definition]

- *Earth System Modeling* _ [definition]
  Framework

- *interface wrapper* _____ [definition]

- *object oriented* _____ [definition]

- *open systems* _____ [definition]

- *operational computing* _ [definition]

- *production computing* _ [definition]

APPENDIX J
Acronym Guide

ARC	Ames Research Center, Moffett Field, CA
ATM	Asynchronous Transfer Mode
CAN	Cooperative Agreement Notice
CAS	Computational Aerosciences Project
Co-I	Co-Investigator
COTS	Commercial Off The Shelf
ESMF	Earth Science Modeling Framework
ESS	Earth and Space Sciences Project
GESCC	Goddard Earth Science Computing Center
GRC	Glenn Research Center, Cleveland, OH
GSFC	Goddard Space Flight Center, Greenbelt, MD
HPC	High Performance Computing
HPCC	High Performance Computing and Communications Program
JPL	Jet Propulsion Laboratory, Pasadena, CA
LaRC	Langley Research Center, Hampton, VA
LT	Learning Technologies Project
NASA	National Aeronautics and Space Administration
NCCS	NASA Center for Computational Science
NREN	NASA Research and Education Network Project
NSI	NASA Science Internet
PI	Principal Investigator
PITAC	Presidential Information Technology Advisory Committee
REE	Remote Exploration and Experimentation Project
SPP	Scalable Parallel Processor
TST	Teraflop/s Scalable Testbed